THE EAST AFRICAN AGRICULTURAL JOURNAL

of

KENYA
TANGANYIKA
UGANDA AND
ZANZIBAR

Vol. XVIII—No. 4

APRIL
1953

IN THIS ISSUE:

Price
Sh. 2/50

THE

EAST AFRICAN AGRICULTURAL JOURNAL

VOL. XVIII—No. 4 APRIL, 1953

Printed and published by the Government Printer, Nairobi

Issued under the Authority of the East Africa High Commission and published every three months—July, October, January, April. Volume consists of four issues (commencing July issue)

EDITOR: D. W. DUTHIE

E.A.A.F.R.O., P.O. BOX 21, KIKUYU, KENYA

Subscription Sh. 10 per volume including postage, payable to the Editor. Subscribers are advised to remit postal orders in payment, otherwise bank commission must be added in the case of cheques.

The Editor does not hold himself responsible for opinions expressed by contributors.

Matter submitted for publication should preferably be sent through the local member of the Editorial Board. Double spacing should be used in typescript. Contributors receive 25 prints of their articles free. Additional copies may be obtained on payment if asked for in advance. Prints bear the same page numbers as the original articles in the Journal, except where, to meet a contributor's wishes, prints are supplied before publication has been completed.

Readers are reminded that all agricultural inquiries, whether they relate to articles in the Journal or not, should be addressed to the local Director of Agriculture, and not to the Editor.

CONTENTS

INDEX TO ADVERTISERS

REHABILITATION WITH GRASS

Current arguments about land scarcity in the African reservations inevitably hinge on the extent to which the widespread visible damage by overgrazing and destruction of vegetation has gone beyond the possibility of restoration. Factual information on the extent of the loss of soil fertility, and on the productivity of the remaining subsoil, is indeed scarce; the carrying capacity of semi-arid land under African peasant farming is a matter on which more facts and measurements are needed for any valid estimate of optimum population density. A recent number of the Empire Journal of Experimental Agriculture (Vol. 21, No. 81, 1952), contains, in a paper by H. C. Pereira and V. R. S. Beckley, the initial results of direct experiments on the establishment of grass on eroded soil in Kenya's semi-arid "Badlands" to the south of Machakos.

The area has a natural vegetation of tall grasses and scattered acacia thorntrees, with a rainfall which has varied, in five years, between annual totals of ten inches and 53 inches, with a mean of about 20 inches per year. Under these conditions the paper reports the carrying capacity of a nearby European-owned ranch. Here a labour force of 1,350 Wakamba of all ages have maintained themselves for the past 30 years on an area of 5,600 acres (approximately 150 people per square mile). Under vigilant supervision, they have required two-thirds of an acre of terraced cultivation per person and 7½ acres of rotationally grazed rough pasture per beast, for full maintenance without deterioration of soil or vegetation. In the adjacent Ukamba Reserve the overall population is only a little higher, at about 166 to the square mile, but the larger number of grazing animals, kept for traditional reasons, reduces the grazing area to an estimated three to four acres per beast. The lack of agricultural skill and discipline of this pastoral tribe further reduces the efficiency of land utilization, so that the denuded and eroded country (in which the experiments are sited) offers a painful contrast to the well-managed lands of the supervised ranch labour force.

The experiment was made possible by the co-operation of the Machakos African District Council, who were persuaded by the District Team to arrange for the temporary evacuation of an area of badly overgrazed and eroded land, on which restoration experiments were to be conducted for an initial period of five years. The altitude is 4,900 ft. and the red sandy soil is derived from gneiss and schist of the Basement complex. In spite of surface erosion the depth of subsoil is four to five feet, which permits adequate root range and moisture storage.

The paper sets out the information obtained in the establishment phase of the experiment, in which cultivation methods, cattle manure and four grass species were tested in a factorial experiment on 32 one-acre paddocks. The paddocks were set out on the contour for safe cultivation.

Shallow scarifying of the surface soil was compared, in factorial combination, with contour ploughing to a depth of six inches, and with contour ridging by potato ridging equipment mounted on a light tractor; dry cattle manure at ten tons per acre was a further treatment. One half of each plot was deeply ripped with a Le Tourneau ripper pulled by a track-layer. Two planted grasses, *Cynodon dactylon* (Star-grass) and *Panicum coloratum* (var. *Makarikariensis*) and two sown grasses, the Trans Nzoia strain of Rhodes grass (*Chloris gayana*) and a mixture of local indigenous *Cenchrus ciliaris* and *Eragrostis superba,* were tried out under severe drought conditions.

The first two years severely tested the establishment techniques; rain fell on only 35 days in 1949 to give a total of 10.13 inches, while in 1950 there were 48 wet days and 16.71 inches total rainfall.

Under these circumstances no grazing at all was achieved in the first year, but late in the second year, grazing at the heavy rate of one beast per acre was obtained for two months on the Rhodes grass paddocks, for six weeks on the *Makarikariensis* and for three weeks on the Star grass.

In the third year, 1951, the remarkable total of 53.12 inches was received in 85 days. This served to illustrate the residual fertility of the "badlands" area. All 32 paddocks stood up to very heavy grazing to give a 12 months average of one beast to 1.68 acres, while many of the paddocks carried more than one beast per acre during this exceptional year. The plots were divided into 64 half-acre paddocks for ease of grazing control.

Measuring the success of the various preparatory treatments by the number of grazing days secured, the authors conclude that these were substantially increased by ploughing, by manuring, and by the incorporation of the manure in contoured ridges. Deep ripping of the soil did not improve either grass establishment or moisture storage. Ridging conserved available soil moisture within reach of the grass roots through two months of dry weather. In the drought years, planting of grass was the only successful method, while in the wetter seasons sown grasses were rapidly established, and equalled the yields of the grasses planted earlier. Effects on soil structure are as yet small, and improvement, under semi-arid conditions, appears likely to be slow.

The experiment has been expanded to include 16 further paddocks of naturally regenerated grasses; after three years of complete protection, together with the essential cutting out of bush, these are making encouraging progress.

Further seasons of variable rainfall are necessary for any valid assessment of the carrying capacity of these pastures under controlled rotational grazing, but the results to date give grounds for cautious optimism about the agricultural factors of the problem. The sociological obstacles to the adoption of such efficient agriculture remain formidable.

FIELD MOISTURE BALANCE IN THE SHIMBA HILLS, KENYA

By C. R. Hursh*, U.S. Forest Service, Head of Division of Forest Influences, S.E. Hydrological Laboratory

and

H. C. Pereira, Soil Physicist, E.A. Agriculture and Forestry Research Organization

(*Received for publication on 17th March,* 1953)

The Shimba Hills are important as the source of water supplies for the town of Mombasa and vicinity. There is now a programme to conduct the waters of Mzima Springs to Mombasa by pipeline. However, the completion of this programme will not lessen the need for local water resources. The Coast area south of the Kilindini estuary, where important industrial expansion is already under way, will depend upon local water supplies. Hence catchment management to provide maximum yields of water from the Shimba Hills will always be important to the coastal area.

In recognition of the importance of the water resources of the Shimba Hills the proper catchment management for the area has been a question of considerable interest and concern. In a Government report prepared by the Hydrographic Survey, Coast Division, Public Works Department in 1949 [1], the need for proper land utilization for catchment management has been stressed, and specific recommendations are given as to how this can be best achieved. It is pointed out that small portions of the Shimba Hills still remain in a dense forest but that the majority of the land is open grassland. The comparison is then drawn as to the relative effectiveness of these two types of vegetation for water resource conservation for the Shimba Hills catchment.

Particular attention is drawn to the sparse grass cover that is the result of annual fires. It is stated with regard to the grasslands: "The rest of the area is open country, covered by grass, which in some places grows thickly, but is generally found in clumps about 6 in. in diameter and 9 in. to 36 in. apart. Where grass fires have been most frequent these clumps are most sparse. Between the clumps the soil surface is visible, either as bare soil, or if fires have been recent, covered with fine carbonaceous material". It is further stated that: "The grass clumps have fine, interwoven roots extending some 12 in. to 24 in. below ground level, the average being 18 in. The roots spread out, so that even when the clumps are separated by 12 in. to 18 in., their roots are still interconnected beneath the surface and form a continuous mat below ground level, which helps to bind the surface soil together. As the clumps are thinned out more and more by fires, this mat will presumably thin out also, and its effect become less. Samples of the grass clumps were dug out and observed at several points over the area; the grass appeared to be of the same type throughout, and the above observations apply for the whole area. The main difference was in the spacing of the clumps of grass".

In view of this very limited amount of vegetation present on the grass area it is concluded that transpiration would be less than from an area of more dense vegetation. Also it is assumed that of the water entering the soil mass, a larger proportion would become available for recharge of the ground water aquifer supplying streamflow.

The present note reports some results of an additional survey of catchment conditions made in the Shimba Hills during the months of June and October, 1952. Because some of the results touch upon broad aspects of catchment management of general interest, they are presented here as a basis for further discussion.

In the present survey the writers were able to confirm the sparseness of the grass cover. During the growing season one's first impression is that the open areas are apparently well covered with grass. A closer inspection reveals that the grass clumps actually occupy less than 40 per cent of the ground surface. Between the

* Under the provisions of the American Fulbright Act, the senior author was attached to the E.A. Agriculture and Forestry Research Organization for the year 1952, during which an extensive study was made of East African conditions. A full report and recommendations on "Forest Management in East Africa in relation to local climate, water and soil resources" is published in the E.A. Agriculture and Forestry Research Organization Annual Report for 1952.

clumps the soil is completely destitute of any plant cover to provide protection against the direct action of the tropical sun. Surface temperatures of 120° to 140° F. were observed during midday.

The natural plant succession in any locality is an important factor in catchment management. The drainage patterns within the Shimba Hills were developed under a dense closed forest, remnants of which still exist. This is certainly not an area of natural grassland. In fact the present so-called grassland has only been created from land once under intensive cultivation, then abandoned and burned over continuously. Practically only one grass species survives. This is an *Andropogon* species that characterizes burned areas of depleted fertility throughout the world. It does not form a true sod but grows only in isolated separate clumps. It is not very palatable and nutritious for livestock or game except when quite young and succulent and it furnishes a very inadequate cover for water conservation. If left alone without fire the plant succession soon passes to a bush stage. Under good forestry it could be changed to a closed tropical forest similar to the natural remnants still remaining in the locality.

If it were feasible to establish a ley of sod-forming grass species this would of course be a reasonable procedure in some localities. Unfortunately there exists considerable misunderstanding regarding the use of grass for catchment management. The term grassland is used much too loosely in East Africa and has been applied to vegetative types ranging from almost bare ground to elephant grass jungles. Some species of grasses on poor, dry soils are quite shallow rooted and have only a very short growing period. Others, like Kikuyu grass, on deep aerated moist soils develop a very deep root system and grow for most of the year. They utilize all the soil moisture available, for example Kikuyu grass near Nairobi has removed a measured 36 in. of water from the first ten feet of soil in the two dry periods of last year (1952). Except for a few favoured locations good grassland is difficult to maintain in tropical countries. As a rule, grazed grassland, as the term is commonly used, is a decidedly unsatisfactory vegetative cover for catchment management. One has only to look at the thousands of square miles in East Africa that have deteriorated through unsupervised grazing, to be convinced of the difficulties of this type of catchment management.

In the Shimba Hills it would certainly be impossible to maintain an improved ley sod without well-managed intensive grazing. Before intensive ley management can be considered as an alternative type of catchment management for these hills the nature and fertility of the local soils, local climatic seasons, and probably most important, the local water economy as expressed by the field moisture balance, must all be considered.

The soil mass is described in Government reports as being a deep porous sand through which water passes, "with great rapidity, possibly due to the large grain size". The only evidence given for this statement is that "although many steep slopes in the catchments have become so denuded of grass as to render erosion easy with ordinary soils, there has been practically no soil erosion in the hills".

In the present survey the sandy nature of the surface soil was confirmed but the entire soil profile did not meet this description. A sandy soil was encountered only to a depth of about five feet. Then an exceedingly impervious clay zone was encountered. Clay zones of this kind are not uncommonly found under relatively porous surface soil horizons. They are known to retard percolation of free ground water and hold it sufficiently close to the surface so that when other conditions are favourable to rapid evaporation from exposed soil the water comes back into the atmosphere instead of contributing to the ground water recharge of underlying aquifers.

Data collected in adjacent forest and grassland conditions, both typical of the catchment area, are set out in Figure 1. Soil cores 4 in. in diameter and 3 in. deep were collected by a sleeved sampling tool from the faces of a freshly dug deep pit in the grassland, and from shallow pits in the forest. After vacuum-wetting in the laboratory they were tested for percolation rates under a static head of 1 cm. of water. The rates of steady flow are good measures of the relative permeability of successive soil horizons, but they are not, of course, a measure of the actual rate of free flow of water through the whole soil profile. They show clearly, in Figure 1, the impervious nature of the clay zone.

Further evidence of the compact nature of the clay at the 5-ft. depth was obtained by using the core-sampler as a penetrometer. The sleeved cylinder was driven into the soil by an 8-pound sliding hammer, mounted on the

handle. This was allowed to fall through a standard distance and the number of blows for each 3-in. penetration of the cutting edge was recorded. The very high resistance at 5 ft. is evident from Table 1.

TABLE 1—COMPACTNESS OF SOIL IN GRASSLAND

Mean No. of Penetrometer Blows per 3-in. Core

0–3 in.	33
3–6 in.	28
at 1 ft.	20
at 2 ft.	28
at 3 ft.	25
at 4 ft.	31
at 5 ft.	92

The root range of the grass was observed to be confined to the soil above the clay horizon, whereas auger samples within the forest showed the clay zone to be full of live roots. The roots of this type of tropical forest have been seen in Kenya railway cuttings and other exposures to penetrate to depths of over 30 ft. Under tall forest the clay layer is thus frequently perforated by roots. The contrast between soil conditions under forest and under the long-established sparse grassland can also be seen from the behaviour of young trees. Mvule plantations some four miles from the sampling site showed that individual trees became established with great difficulty because of climatic exposure and unfavourable soil conditions in the grassland, whereas saplings were growing freely on the edges of the forest areas, following on the pioneer growth of the vigorous peripheral scrub, whose roots penetrate the clay layer. Under similar soil conditions in the United States of America this effect is utilized in forestry practice by peripheral planting.

Periods of Ground Water Recharge

It is a well-known hydrologic fact that ground water recharge takes place principally when there is no field moisture saturation deficit, that is when all the capillary moisture requirements have been satisfied. These periods of the year are not frequent even in regions of considerable rainfall. When these periods do occur, for example after an accumulation of 4 to 6 in. of rain falling within a period of a few days, the amount of ground water recharge depends solely on soil conditions favouring rapid downward percolation. Consequently a major objective of catchment management is to create and maintain local soil conditions that favour rapid infiltration and percolation of free water through the entire soil profile. In the Shimba Hills the natural forest creates more favourable conditions for percolation of free water through the entire soil mass than does the present *Andropogon* grass cover.

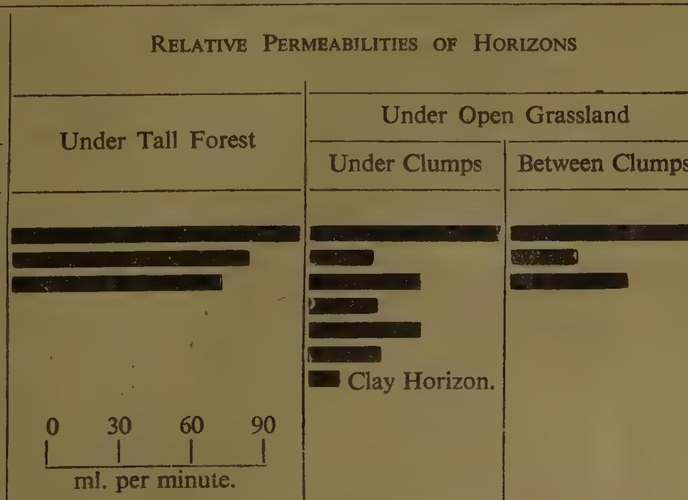
Evaporation from Soil

Several distinctive soil conditions contribute towards increasing the amount of moisture evaporation from the grass area within the Shimba Hills. The bare areas of exposed sandy soil between the grass clumps absorb the sun's rays and conduct the heat deep into the soil profile. In mid-November of 1952 temperatures of over 80° F. were recorded at a depth of

FIGURE 1

SOIL TEXTURE (% Oven Dry Soil)

Depth	Clay	Silt	Sand
0—3 in...	10	21	69
3—6 in...	18	13	69
At 1 ft. ..	20	13	67
At 2 ft. ..	26	11	63
At 3 ft. ..	28	15	57
At 4 ft. ..	44	19	41
At 5 ft. ..	46	22	34



4 ft. under representative grass cover. These unusually high soil temperatures did not change greatly throughout the day and night. This is shown in Table 2.

It will be seen from the data given in Table 2 that at night the temperature gradient under grass would result in the vaporization of moisture in the porous sandy horizon of the soil. Its movement towards the cooler surface would result in either loss as evaporation, or, under favourable circumstances, to condensation near the surface where it would become subject to evaporation the following day.

Under the forest trees the soil is insulated against the sun both by the foliage and by the porous litter mulch. The result is that evaporation is reduced to a minimum, and soil moisture losses by evaporation are not a significant factor in the field moisture balance. Under the present grass cover outside the forest, evaporation from the soil is of paramount importance and accounts for much of the field moisture losses that take place. Free water, trapped and held above the clay horizon for considerable periods is subject to vaporization, in porous sandy soil that becomes heated by direct rays of the tropical sun. Soil moisture can thus be lost through evaporation, long after capillary film movements have ceased.

Pans with an area of 2 square feet, and some 3 in. deep, were filled with sections of surface soil from grass clumps, bare soil between clumps and forest litter respectively. The samples, in triplicate, were exposed *in situ*, the pans being sunk to bring the samples into the plane of the soil surface. The pans were weighed a few minutes before sunset, and again before sunrise (a procedure complicated by the presence of elephant and buffalo in the forest edge). A newly calibrated thermohygrograph was operated among the grass clumps and recorded 100 per cent R.H. and 70° F. for 12 hours on the three successive nights of this test (24th, 25th and 26th November, 1952). The grass was covered by beads of moisture but the gains in weight were very small, amounting to less than 1 millimetre of surface water in all samples. Heavy condensation of water occurred on the underside of the pans in the open grassland and under dishes inverted over bare soil. This was two or three times the weight of the dew, but no satisfactory quantitative methods of measurement could be improvised from the apparatus available on the spot. No such condensation occurred in the forest samples.

The capacity of the soil for water above the clay layer has been calculated from tension-table measurements made on the profile sets of soil cores. At 20 cm. of water tension, which reproduces the approximate conditions at the end of a wet spell in which rain sufficient to fill the soil has fallen, the grassland holds 20.7 in. and the forest 20.4 in., in the first 5 ft. of soil. At the time of sampling, the forest soil held 12.8 in. and the grassland 13.1 in., within this depth. Evaporation and transpiration from the sparse grassland and the heavy forest had thus caused equal losses from above the clay layer.

Effect of Dew and Mist

Because the sea breeze coming from the nearby Indian Ocean is practically saturated with moisture, dew occurs throughout the year in the Shimba Hills. However, the amount of dew varies for different seasons. The cooler

Table 2—Air and Soil Temperature Under Light Grass Cover

Shimba Hills—Beginning noon 26-11-52, *ending* 9 *a.m.* 27-11-52

(Temperatures in Degrees Fahrenheit)

	12 noon	3 p.m.	7 p.m.	12 Mdt.	6 a.m.	9 a.m.
Air Temperature at 3 feet	87·0	80·0	73·0	69·5	70·0	83·5
Air Temperature at Ground Surface ..	99·0	82·5	74·0	69·5	71·5	85·0
Soil Temperature at 1 in.	106·0	94·0	80·0	73·0	72·5	87·0
,, ,, ,, 6 in.	83·0	88·0	89·0	83·0	80·0	82·0
,, ,, ,, 12 in.	82·0	83·5	85·5	84·0	82·0	82·0
,, ,, ,, 18 in.	81·0	82·0	84·0	82·0	81·0	81·0
,, ,, ,, 24 in.	81·0	81·5	83·5	82·0	81·0	81·0
,, ,, ,, 36 in.	80·0	80·5	82·0	81·5	80·0	80·0
,, ,, ,, 48 in.	80·0	80·0	81·5	81·0	79·0	79·0

temperatures accompanying the Southern Monsoon not only produce a heavier dew but they are also accompanied by heavy mist and fog. The mist collects on all plant parts with which it comes in contact. Likewise the dew will condense on all the leaves and stems that radiate heat fast enough to become cooler than the saturated night air. Consequently the amount of water collected in a specific location depends on the sum total of surface area of plants present. In the dense forest there are several layers of vegetation in addition to numerous vines that climb through all the layers. In the forest of the Shimba Hills the first layer above the ground consists of dense evergreen shrubs 3 to 5 ft. high. Next there is a layer formed by the branches of low trees whose stems range from 3 to 5 in. in diameter. Then there is an understorey of sub-dominant trees. Finally there is the closed upper canopy of dominant trees which may be from 100 to 140 ft. above the ground surface. Considering the amount of leaf and stem surface on which mist and dew can collect it is apparent that the plant surface in the grassland is but a very small fraction of that exposed in the forest. Also the significance of such condensation as does occur in the grassland is less since all such moisture disappears soon after it is exposed to the sun. On the other hand, the dense forest may continue to drip moisture well past mid-morning, because the fog and mist tend to remain in the forest for several hours longer than in the open.

In summarizing the above processes it can be said that during the period of the North-east Monsoon the total heat absorbed during the day tends to keep the night temperatures higher and there is less dew formation. During the cooler months from April through August the South-east Monsoon is accompanied by heavy mists that drench the forest canopies in addition to heavy dew formation. The result is an almost continuous fog drip in the forest and this contributes a very important amount of moisture to the water economy of the forest areas. Litter and soil samples taken in the forest near Kwale during June, 1952, showed a daily increase of about one-tenth of an inch of water in the upper 6 in. of mineral soil, and a similar increase within the litter and debris mulch overlying the mineral soil. More detailed measurements would be required to estimate the exact amount of moisture that is added to the water economy of the forest in this manner, but this type of dew and fog drip is not uncommon. For example, in a somewhat similar coastal forest in Oregon it was found by measuring the fog drip caught in rain gauges that 11.25 in. of extra water was accounted for in this manner during a period of 142 foggy days [2]. That this type of moisture can be important in the Shimba Hills can be deduced from the fact that the natural high forest remnants contain large trees of the same species that are normally found only in areas known to receive from 80 to 120 in. or more of rainfall. The rainfall records taken near the District Commissioner's station at Kwale in a standard 5-in. gauge show an average annual rainfall of only 41 in. Since this is considerably less than the amount considered as necessary for a high tropical rain forest one can only conclude that the tree growth must be supported in part by other types of recharge of moisture than is measured as rainfall in standard types of rain gauge.

The fact that fog drip and dew do not appear to occur in large amounts at any one time when expressed on an area depth basis, has led many observers to conclude that these processes cannot be of any real significance in the total water economy of an area. A more thorough consideration of all water cycle factors does not justify such a conclusion. For example, during the hours when fog drip and heavy dews are present, evaporation and transpiration of field moisture are reduced to a minimum. The net result is to conserve such field moisture as is already present in the soil. Consequently since the soil dries out more slowly the water cycle will be operating under condition of a higher sum total water economy. There will be less field moisture saturation deficit and consequently less rain will be required before ground water recharge can take place. In other words the circulating water capital in the water economy of the forest is always greater than that of open grassland. This fact alone is of paramount importance in appraising the water economy of different land-use programmes for tropical countries.

Thus in comparing the water economy of the forest and grass vegetation in the Shimba Hills all the processes of the field moisture balance must come under close review. For example, although there is more canopy interception in the forest, this is offset by a much greater recharge of moisture from the condensation of mist and dew, and at the same time there is a total saving of field moisture drawn upon by the trees. Total transpiration is doubtless

higher in the forest, but evaporation of soil moisture is almost insignificant. In the grassland the evaporation of field moisture becomes the most important form of water loss, due to the nature of the local soils and the associated high soil temperatures. During the occasional periods favourable to ground water recharge percolation of free water through the deeper clay horizons will be more rapid under the forest. These plus and minus values that must be added together in the solution of the comparative field moisture balance between two vegetation types present a complex problem. Measurements of all the components of the water cycle continuously throughout the year is admittedly a logical approach to the solution but not necessarily the most practical one. For comparison of two adjacent covers, the quantitative (volumetric) study of the soil moisture changes within their respective root ranges, and the continuous recording of soil moisture tension conditions under both, together provide an adequate measure of their relative effect on the water cycle. The duration of conditions suitable for recharge of aquifers below the root-ranges, and the summation of rainfall within these periods, is itself a comparison which may decide an issue of catchment management policy. No measurements of this daily march of field moisture have ever been made in the Shimba Hills although technics for obtaining water measurements have been greatly improved during the past decade.

Streamflow measurements have been made in the Shimba Hills for many years for the purpose of estimating minimum dependable water yields. These measurements are taken mainly as instantaneous spot readings and are not adequate to reconstruct a continuous hydrograph of streamflow. They can be used to develop an approximate base flow hydrograph valuable in roughly indicating the seasonal period of accretion and depletion of ground water. Because no watershed boundaries have been surveyed in the field it is quite impossible to compute actual unit yields for different catchments, for example cubic feet per second per square mile of catchment. There are two other complicating factors, one is that watershed boundaries are indistinct for many of the catchments in the northern half of the Shimba Plateau due to the water level topography. Another is that in geological formations of this type several streams may have a common ground water aquifer. However, there is one drainage basin that merits intensive study in terms of independent catchments. This is the drainage area of the Mwachemwana River in the south-eastern portion of the plateau. Here the natural topography is such as to provide fairly definite watershed boundaries. Streamflow within this drainage basin represents the outflow from definite catchment areas and can be used to compute unit yields. No satisfactory rainfall measurements are available for the Mwachemwana River basin. However, streamflow records show that this river has a well-sustained base flow. For experimental purposes the basin can be divided into a number of independent catchments each with a permanent streamflow. The fact that much of the Mwachemwana River basin is in dense forest and bush detracts from conclusions reached in early reports that forests were unfavourable to high yields of water in the Shimba Hills. On the other hand it is most probable that if unit yields were determined for the Mwachemwana River drainage basin, they would compare very favourably with unit yields from important water-producing catchments outside of the Shimba Hills. It is unfortunate that no suitable data are available for estimating the water balance for the Mwachemwana basin as it is one of the few really desirable basins for hydrologic studies on the whole coastal area of East Africa [3].

Accurate streamflow records on which to compute the continuous unit yields of water when combined with rainfall data taken on independent catchment areas are valuable aids in interpreting land-use hydrology. However, such records as are available for the Shimba Hills are quite inadequate for this purpose. Some of the stream gauging stations already installed could be used for future catchment studies if the records were taken by means of suitable continuous water-level recorders.

Until the substantiating water yield data have been collected the writers can only express an opinion based on observations of the field moisture balance in the Shimba Hills. These observations point to the logical conclusion that under the natural forest which once occupied the Shimba Hills the water economy then favoured maximum sustained water yield. Such changes in vegetation as have taken place have resulted in changes in the field moisture balance leading to a reduction in the total circulating water capital and in the total water yield. It is considered that the re-establishment of the dense forest in this natural coastal mist belt will be the greatest insurance possible for

obtaining the maximum yield of water from the Shimba Hills.

Trees and shrubs should, however, be cleared from the margins of the streams as a matter of routine catchment area management. Such vegetation, with roots reaching the water tables fringing the streams, has been shown by catchment area studies in other countries to cause a serious loss of water yield. Thus by planting of valuable forest trees on the high ground, far above the water table, while removing valueless and thirsty scrub from the margins of the streams, condition for maximum water yield could be achieved for those hills.

REFERENCES

[1] Anderson, D., and Starmans, G. (1949).—"Preliminary Investigation of Water Resources of the Shimba Hills." File Report by the Hydrographic Survey, Coast Division, Public Works Department.

[2] Kittredge, J. (1949).—In Report of Commttee on Evaporation and Transpiration: Chairman, H. G. Wilm, Trans. Amer. Geophysics Union, 30, p. 131.

[3] Hursh, C. R. (1952).—Annual Report of E.A.A.F.R.O. for 1952.

BOOK REVIEW

"A Note-book of Tropical Agriculture" by R. Cecil Wood, 5th Edition, 1950, published by The Imperial College of Tropical Agriculture, Trinidad, British West Indies, p. 147, price 7/6d.

No major alterations have been made in this note-book since its first edition in 1933, and the successive editions are a tribute to its usefulness. It contains a wealth of facts and information for farmers in the tropics, all severely practical, and after consulting it over 18 years, the reviewer feels competent to recommend it.

D.W.D.

INVESTIGATIONS INTO DISEASES OF THE CLOVE TREE IN ZANZIBAR

By F. J. Nutman and F. M. Roberts, Clove Research Scheme, Zanzibar

(*Received for publication on 8th March, 1953*)

The islands of Zanzibar and Pemba which, with the Kenya littoral, constitute the Zanzibar Protectorate, produce the greater part of the world's supply of cloves. The prosperity of the islands, the standard of living of the people, and the revenues of the local Government, are largely dependent on this crop.

Two important fungal diseases affect the clove tree, Dieback, now proved to be caused by a new species of *Cryptosporella*, and Sudden death, thought to be caused by a new species of *Valsa* (Nutman and Roberts, a, b and c, in Press). The first is preventable and, except in severe cases, controllable. The second disease, however, has now, particularly in Zanzibar Island, passed beyond the stage where simple control measures are likely to be effective and, unless drastic action is taken, clove production is not likely to survive as a major industry.

In spite of the vital importance of the clove tree to the economy of the Protectorate, and the fact that Sudden death has been known for nearly a century (Tidbury, 1949) this disease remained completely uninvestigated until 1922, virtually uninvestigated until 1939, and it was not possible to assign a cause to it until 1951. This paper is an examination of the reasons why a major plant disease problem remained unsolved for so long.

According to official reports, widespread mortality has in the past sometimes affected the clove plantations. Thus, in 1894, 10,000 trees were reported to have died in Zanzibar Island, and in 1898, 200,000 in Pemba. The Zanzibar mortality was almost certainly due to inundation (Campbell, 1940) while the Pemba deaths can confidently be ascribed to a phenomenal drought, less than half the average rainfall being recorded that year. The disease, however, had very probably been present, although at a low intensity, for a long time. For example, Fitzgerald (1892) wrote that "the percentage of dead, dying, and unhealthy trees was very small". However, by 1907 the disease was sufficiently serious for McClellan, a District Officer trained in forestry, to draw the attention of Government to the dangers of what was obviously Sudden death and said that, in all probability, it was caused by a fungus. He recommended investigation, but no action was taken.

McClellan became Acting Director of Agriculture in 1910, and later Director. He was thus in a position to press his views on the importance of the disease, both Sudden death and Dieback, with great vigour, but was consistently unsuccessful in obtaining action. He did, however, secure the services of Dowson, Mycologist to the Agricultural Department of Kenya, for about two months in 1914. Dowson's actual visit was arranged without consultation with McClellan, and for the beginning of the long rains, when travel in Pemba, which at that time had no road, was almost impossible. His report (1914) was, not unnaturally, quite inconclusive. He observed fungi in diseased trees but thought that they were probably not parasitic, since adjacent seedlings were healthy. His tentative conclusions were that both Sudden death and Dieback were probably due to adverse soil conditions, aggravated by damage done during harvesting in the case of the latter.

McClellan, as Director of Agriculture, was in a rather unusual position. He was "supervised" by a Member of the Protectorate Council, by whom all reports and recommendations were reviewed before they reached the Head of the Government. This person, whose name we have been unable to trace, considered McClellan to be an alarmist, and so convinced the Government of this that an attempt was made, in 1912, to shut down the Department of Agriculture on the grounds that the health and prosperity of the agricultural industry rendered it unnecessary. A recommendation to this effect actually reached the Foreign Office, but fortunately McClellan was able to put his views before the technical advisers to the Secretary of State and the proposal was, consequently, not accepted. Apparently the main argument of the Supervising Member was that since there was no falling off in the clove exports all was well with the industry. This argument, which is still heard in certain quarters, is both fallacious and dangerous, for in a crop such as cloves the

effect of disease is not likely to be reflected in yield until a dangerous intensity is reached.

For many years McClellan continued to urge the need for technical advice and assistance, but his efforts were nearly always frustrated. For instance, after preventing the closing down of the Department of Agriculture the Secretary of State agreed that a mycologist should be sent out, but the Protectorate Government refused to appoint one. Even in 1920 when, on the advice of a Colonial Office Committee, a mycologist was at last appointed, the Administration again tried to cancel the appointment but, the mycologist having already sailed, was unable to do so. Thus the first scientific study of clove diseases began 14 years after McClellan's first warnings. It began, moreover, against the wishes of the Administration, influenced presumably by the Supervising Member referred to before, who, believing that "practical men were preferable to experts" succeeded in overriding, for many years, the advice of the Zanzibar Director of Agriculture and of the technical advisers to the Secretary of State.

It was doubly unfortunate for McClellan and for the future of the clove industry that the worker appointed (Welsford), judging from her reports, was apparently very inexperienced. She might have arrived at more convincing conclusions, however, had she been allowed to work longer on mycological problems.

The symptoms of Sudden death, as she described them, are, with few modifications, those to be observed to-day (Welsford, 1923). She asserted that the disease was fungal, but she did not isolate the organism or conduct any experiments with it, while her description of the fungus which she believed to be the cause would fail to convince any person with any knowledge of mycology. There were no such experts in Zanzibar, however, and her conclusions could not have been challenged locally: they were accepted by the Director of Agriculture and by an Agricultural Commission in 1923.

Incorrect as Welsford's conclusions were as to the cause of the disease, some of the specific recommendations she made for control might well, if put into operation, have slowed down the spread of the disease. These were, in the main, the standard methods usually advocated against fungi which spread through the soil. The disease was also said to be spread by "spores"* and one particularly sound recommendation was the burning of stumps and main roots of dead trees.

Welsford started a number of field experiments to test the methods of control she advocated, but it is certain that these were not kept up. We can find no detailed reecords of them. One had apparently failed ten years later, but, seeing that it had received no attention, this is not surprising (Troup, 1932). She also correctly described the symptoms of Die-back in mature trees, now known to be caused by a species of *Cryptosporella,* but wrongly thought that it was caused in part by a root-rot and in part by a leaf spot.

Armed with Welsford's report, McClellan then reopened the issue, and a vigorous and outspoken memorandum reviewed his attempts, over nearly 20 years, to stimulate action, and requested that it be forwarded to the Secretary of State. This request was not complied with. No action was taken to implement Welsford's recommendations although, as has already been stated, they were endorsed both by the Director of Agriculture and by an Agricultural Commission.

McClellan then retired, not having accomplished what he had endeavoured to do for so long, but leaving behind him a reputation which endures to this day, many Arab agriculturalists still speaking of him almost with reverence†. He was succeeded as Director of Agriculture by a chemist, Kirkham, who promptly found other work for Welsford and "directed her attention to subjects outside the scope of mycology". He wrote that "fears are no longer entertained of the presence of contagious disease amongst clove trees".‡

* We have found no spores which answer to Welsford's description, but Mr. E. W. Mason, of the Commonwealth Mycological Institute, thinks that her fungus was, in part, a species of *Kirschsteiniella.* She did, however, collect and deposit in Kew (I.M.I. 14290) the perithecial stage of the species of *Valsa* to which Sudden death is now ascribed, but did not associate it with the disease.

† In its issue of 16th July, 1952, a local newspaper, *Al Falaq,* says, " . . . we refer to Mr. McClellan who left a good name in these two islands . . . it is incumbent on us to recall the memory of that capable agriculturist, with gratitude to him for his beneficial idea". [*sic*]

‡ We are quite unable to conjecture why this statement was made, especially from a department whose previous Director had consistently maintained that disease was a serious problem, and with no additional evidence whatsoever.

Writing in retirement, Kirkham explained his point of view in these words: "I have never felt anxious on the subject of diseases . . . I sometimes think that clove disease is a red herring drawn across the trail and that activity in scientific research will excuse neglect of more difficult economic problems". He also referred to the Sudden death disease as a "mare's nest".

The attitude of Kirkham, as Director of Agriculture, being what it was, it is not surprising that we can find no trace of any investigational work for some years. In 1931, however, Troup, then Professor of Forestry at Oxford, was asked to visit Zanzibar and to investigate the problems of clove cultivation, disease not being mentioned. He stayed for about four weeks. His report is concerned mainly with silvicultural problems, but does mention the two main diseases of the clove tree. He, not unnaturally, reached no definite conclusions; but he did suggest that soil conditions could not be the cause of Sudden death, and also that Dieback might, in some cases, be caused by a chafer larva. Kirkpatrick (1932) disproved this. Troup devoted much attention to devising methods for the cheap and efficient regeneration of the clove plantations, and recommended interplanting in old stands. He did, however, make it quite clear that this policy was unsound if disease were present, and said that trees which had died from Sudden death should be grubbed up and burnt. This advice has been ignored.

In 1932, Sir Alan Pim, a Treasury expert, in a report on Zanzibar, drew attention to the lack of "any definite scheme for scientific experimental work" and pointed out that "practically no experimental work has been carried out since 1912 by the Department of Agriculture". As a result of this, Troup's recommendation that a silviculturist be appointed was implemented, and an Agricultural Experimental Station was started in 1933.

The silviculturist, Wigg, initiated schemes for sound nursery and plantation practice, and, although most of his work was silvicultural, he concluded, as the result of field observations, that Sudden death was probably due to a root fungus (Wigg, 1937). He, like Troup, advocated the removal and destruction of the stumps and roots of diseased trees, but his recommendations do not seeem to have had much effect on agricultural practice, although they were, for a time, adopted in certain Government plantations.

During this period, recordings of the casualties in selected plantations were being carried out. These show clearly the devastation then being wrought by the disease. For example, three plantation groups lost, respectively, 12.5 per cent, 9.0 per cent and 36.6 per cent of the stand in the decade 1930–1940. Such losses should have caused alarm.

In 1937, Sir Frank Stockdale, Agricultural Adviser to the Secretary of State, visited Zanzibar, and emphasized the very serious nature of the Sudden death disease. He, too, considered a fungal root disease to be the most likely cause of the mortality, and pressed for investigation to be undertaken. As a direct consequence of this, a mycologist (Campbell) was appointed in 1938.

During the interval between Stockdale's visit and Campbell's arrival, Storey, then Plant Pathologist at the Amani Institute, visited Zanzibar. It should be mentioned here that the Amani Institute, over a considerable period of time, afforded such scientific help as was possible, and many visits were paid to Zanzibar by its staff. Most of these visits were, unfortunately, short.

Storey set up some valuable field experiments and collected material for histological study. In the latter he observed the great increase in production of tyloses associated with the disease, and also definite phloem degeneration in the roots. He did not, apparently, see fungal hyphæ, but these are not easy to see in the early stages of the disease and, in our experience, need special staining. Furthermore, his material was collected in Zanzibar during a very brief visit and examined at Amani and must, therefore, have been limited.

Storey concluded, correctly, that the observed degeneration of the phloem was associated with the disease, and considered that it was probably caused by a pathogen, the suggestion being that it might be a flagellate infection of the phloem or possibly a virus. He also urged the necessity of investigation by a plant pathologist.

Gibbins, Horticulturist at the Amani Institute, attempted to transmit the hypothetical flagellate by grafting, but failed to secure successful unions. In view of what we now know about the difficulties of grafting the clove, this is not surprising.

The mycologist, Campbell, appointed as a result of Sir Frank Stockdale's recommendations, spent rather less than a year in the Protectorate, although the Director of Agriculture (Miller) had previously stated that he considered so short an appointment to be a waste of money. After his return to England, and after considerable delay, he submitted a lengthy report.

Campbell failed to find any evidence in support of a phloem flagellate, but isolated several fungi from diseased trees. Unfortunately, he left no descriptions of them. The experiments which he carried out with these fungi were not likely to have established whether any of them were pathogenic or not; his sole test of pathogenicity being whether mature clove trees, inoculated at a single point in their trunks, were still alive after the inadequate period of nine months. These experiments having, naturally, failed, Campbell asserted that Sudden death was not due to a pathogen.

It is now a matter of surprise that, at that time, so many high authorities should have accepted Campbell's conclusions without perceiving that his evidence could have been interpreted in favour of a fungal pathogen, and that the staff of the Clove Research Scheme should, at first, have fallen into the same error. Campbell actually observed and described invasion by fungi of the absorbing roots in the earliest recognizable stage of the Sudden death disease. He also carried out extensive sampling, by increment borer, of the collars of healthy, diseased, and dead trees, and made both microscopic and cultural tests on the bores. Out of 928 samples, 68 per cent of those from diseased trees showed the presence of a fungus, and 43 per cent yielded one particular one. Only 7 per cent of the samples from healthy trees yielded fungi, not a particularly high proportion for casual contaminants. It seems to us more than likely that the fungus which Campbell isolated most frequently was actually *Valsa*.

Campbell missed, or failed to mention, two important phenomena associated with Sudden death. Firstly, the wood of all trees which have died of the disease is stained a brilliant yellow.* This is a conspicuous feature of the firewood seen being transported to Zanzibar Town from Sudden death areas. The stain is first seen, before the death of the tree, in the distal parts of the root system and it spreads upwards after death, colouring the trunk and larger branches. It is a product of *Valsa* sp., and is also produced in the laboratory in pure cultures of the fungus. Secondly, although like Welsford, Campbell collected the perithecial stage of this fungus, and deposited it at Kew (I.M.I. 44926) he, also, did not associate it with the disease. These perithecia are always to be seen about three months after a tree has died of Sudden death, at first in the region of the collar, and later all over the trunk and larger branches. We have never found them on any tree which has died from any cause other than Sudden death, and never on any tree other than the clove. These two signs alone should have provided clear indications that a fungal pathogen might be involved.

As regards Dieback of clove trees, Campbell distinguished between a young and a mature tree form. He described as "Dieback" of young trees what we now describe as "Slow Decline" and correctly associated this with a root-rot occurring in young replants supplied to sites of previous Sudden death casualties. He pointed out the need for further mycological study of this condition.

He also studied Dieback of mature trees, but, surprisingly, confined his attention to their root systems, which he found to be normal.† He suggested, tentatively, that disturbed water relations might be the cause of this disease.

During the latter part of Campbell's stay in Zanzibar, when he had virtually abandoned any belief in a pathogenic hypothesis, short visits were paid by Milne, Herklots, Glover and Nutman.‡ Milne reviewed soil problems and

* It is a remarkable fact that not only Campbell, but everyone else who has worked on and lived with the clove tree in Zanzibar has, even if they have observed it, failed to connect this very obvious phenomenon with Sudden death. A present senior member of the Agricultural Department, for instance, now remembers that a presentation clove-wood casket made for Wigg when he left the Protectorate was "as yellow as a guinea".

† Mature tree Dieback, caused by *Cryptosporella eugeniæ* (Nutman and Roberts, in Press), is an extremely obvious case of attack by a virulent wound pathogen, accompanied by conspicuous red-brown staining of the wood and by readily observable fructifications.

‡ Milne, G., Soil Chemist, Amani.

Herklots, G. A. C., then Professor of Botany, Hong Kong.

Glover, J., Plant Physiologist, Amani.

Nutman, F. J., then Plant Physiologist, Amani.

suggested that a soil survey might be undertaken. Herklots and Nutman both developed a physiological hypothesis as bases for future study. Glover (1939), the only one to carry out actual research, studied the root system of the clove in some detail. He also investigated the transpiration rates of diseased and healthy trees, and showed that water loss was greatly reduced in the diseased trees. Nutman (1950) later confirmed and extended these observations.

However unjustified Campbell was in so summarily dismissing his own evidence in favour of a fungal cause of Sudden death, his gravest error was that he did not realize that all he could claim to have done was to have failed to find a pathogen. His excuse, if one were needed, could have been that his stay in the Protectorate had been too short to have done more.

Instead of this, however, he asserted the absence of a pathogen and then put forward, with great vigour, a physiological hypothesis, unsupported by any experimental evidence whatsoever. Campbell found himself unable to suggest any explanation for the start of an outbreak, but considered that once the first tree had died, the effect of breaking the canopy would be to initiate a series of deaths because of some disturbance in the water relations of the trees.* Actually, if the canopy of a mature stand is broken experimentally, the effect on the remaining trees is to cause them to grow with increased vigour. Campbell did not carry out such an experiment.

The Zanzibar Government, apparently at the time somewhat dubious about Campbell's conclusions, suggested that his report be submitted to a group of acknowledged experts in the United Kingdom and in East Africa; at Campbell's own suggestion it was also submitted to several plant physiologists. Among those who read the report, Sir John Russell, Storey, Wallace, and Skene† all emphasized that they did not consider that the possibility of a pathogen as a cause had been eliminated, Storey saying "failure to demonstrate a pathogen is not synonymous with proof of absence". Bawden, quoted by Sir John Russell, was "quite definite in his view that the symptoms suggest a virus", a suggestion which had also been made earlier by Storey.

In spite of these doubters, Campbell's views became generally accepted, the Director of Agriculture (Muir) writing, "Dr. Campbell's visit has satisfied us that the disease is not due to a pathogen. To that extent we do not fear that the condition will sweep through all the clove trees in the Protectorate". Campbell, later, in 1942, made recommendations for the regeneration of clove plantations affected by Sudden death, and stated categorically that "there is no reason, then, to fear that the Sudden death condition will prevent successful regeneration on the sites of former casualties".‡ This is essentially the view taken by all the Directors of Agriculture in Zanzibar since Mr. V. H. Kirkham.§

Following Campbell's visit, the chief problem was considered to be one of regeneration on the affected areas. The clove tree is difficult to establish, since forest conditions suit it best. Troup's recommendations, that underplanting would probably prove to be the best method of regeneration, had been confirmed by extensive experiments carried out by the Department of Agriculture, and this method became the one officially recommended. Unfortunately, the warnings of both Troup and Wigg, that underplanting must not be resorted to where disease was involved, were ignored and we find Muir, Director of Agriculture, stating: "We are satisfied that in plantations where Sudden death has become considerable the interplanting of lines of seedlings between the rows of old trees is the solution".

We find it almost impossible to believe that methods which so flagrantly violate every principle of good plantation management should

* One of Campbell's reasons for dismissing a fungal hypothesis was that, on it, he was unable to account for the start of an outbreak.

† Sir John Russell, then Director, Rothamsted Experimental Station.
Storey, H. H., then Plant Pathologist, Amani Research Station.
Professor Wallace, Director, Long Ashton, Bristol University.
Professor M. Skene, Professor of Botany, Bristol University.

‡ The emphasis being placed on regeneration during and before this period led to some surprising results. Thus, in 1934, Findlay, then Director of Agriculture, was of the opinion that the primary cause of Sudden death was "evidently a root fungus" yet at the same time he was so concerned with increasing the proportion of the younger age-classes that he considered that "the disease is not without its advantages as it attacks and kills only older trees. . . . "

§ Kirkham succeeded McClellan as Director of Agriculture.

ever have received official sanction by agricultural experts, especially since scientific opinion on Campbell's conclusions was by no means unanimous. In fact, the present Director of Agriculture, a mycologist, Briant, then an officer of the department, emphasized, some years after Campbell's departure, that Sudden death might well be caused by a pathogen (Briant, 1946.)

There are now many thousands of young saplings in Zanzibar which have grown up on areas previously devastated by Sudden death. Many of these are now affected by the disease which we have called "Slow Decline", and which we consider to be the result of infection by *Valsa* of young trees which still retain a certain degree of juvenile resistance.

During the second world war research was in abeyance, partly because of the war and partly because it was then considered in Zanzibar that there was no danger of the disease getting out of hand; this despite the fact that in one group of Government plantations, originally comprising 27,916 trees, no less than 10,121 had died from Sudden death during the previous decade. Dieback also steadily increased without, apparently, exciting particular interest or comment.

In 1946, following a visit by Sir Harold Tempany, then Agricultural Adviser to the Secretary of State, it was decided to reopen investigations into the problems of clove disease, the Department of Agriculture having been anxious for work to be done for some little time. A scheme of research, financed mainly from Colonial Development and Welfare funds, was initiated, and as the disease was still thought to be physiological, a plant physiologist, Nutman, was appointed as Director. After a preliminary visit to Zanzibar in 1946, Nutman stated that every observable characteristic of the disease pointed to its being of pathogenic origin.

At this stage there were many hypotheses in the field, some fantastic—but many of them had to be considered.* Nutman's preliminary observations (later confirmed in 1949 by the extensive field studies of Nutman and Sheffield) that the spread of the disease resembled that caused by a pathogen eliminated, at least provisionally, physiological and pseudo-physiological explanations. A root fungus seemed unlikely because an experienced mycologist had recently searched for one and found none that he considered could be pathogenic. Storey's flagellate hypothesis, influenced by Stahel's work on coffee, had received no support from his own or from Campbell's investigations. Storey and Bawden had both suggested that a virus might be implicated, although the nature of the disease was in some respects different from that of any known virus disease. However, a virus causation was by no means impossible, and was adopted as a reasonable working hypothesis. The staffing of the scheme was, therefore, arranged accordingly, the senior members for the first year being, in addition to Nutman, a cytologist with virus experience (Sheffield) and a horticulturist (May).†

Nutman and Sheffield showed that the disease could only be caused by a pathogen, and suggested that it might be a virus transmitted by the most common insect of any kind on the clove tree, the coccid *Siassetia eugeniæ* Way. This insect is carried from tree to tree by the ant *Oecophylla longinoda.* Unfortunately, although this hypothesis was put forward tentatively and on purely circumstantial evidence, Nutman and Sheffield's paper has been interpreted by some uncritical readers as being a claim to have proved that Sudden death is caused by a virus, although the authors were careful to point out that a fungal causation was not excluded.

Their investigations showed that, beyond control in Zanzibar, the disease had already reached an intensity in Pemba which made some attempt at control a matter of urgency. Posnette‡ visited Zanzibar early in 1948 and said that "the manner of death, symptoms, pattern of spread and absence of a visible pathogen, support the hypothesis that Sudden death is caused by a virus which is transmitted by a comparatively slow-moving vector".

* We have a list of over 40 of these suggestions. They include "poison on the spears of the mainlanders", made by the Editor of one of the local newspapers; "heat from subterranean deposits of radio-active minerals", also made in a local newspaper: "iodoform in the soil", a suggestion put forward in a series of Memoranda by a local surveyor, G. B. Campbell (not to be confused with Campbell the mycologist), and, "*Verticillium albo-atrum*" which was claimed by A. Lenard, in an article in the local Press, to cause both Sudden death and Dieback. (The mean annual maximum temperature of Zanzibar is 84° F., and of Pemba 86° F.!)

† W. B. May. Now at E.A.A.F.R.O.

‡ Dr. A. F. Posnette, Senior Pathologist, West African Cacao Research Institute.

Shortly after this, an Advisory Mission consisting of Bawden, Hall, Martin and Storey* visited the Protectorate. This visit was made in connexion with an abortive control scheme. (Nutman, Sheffield, Swainson and Winter, 1951.) The Mission stated that they "saw nothing to conflict with the hypothesis of a virus disease", but emphasized that the evidence was solely circumstantial, and strongly recommended the extension of research and the strengthening of the staff of the Clove Research Scheme.

At the beginning of 1950 the team was augmented by the arrival of an entomologist (Way) and a plant pathologist (Roberts) and for a time investigations were continued on the virus hypothesis concurrently with mycological work and insect surveys. During the preceding two years, and in the early part of 1950, every possible way of proving the virus hypothesis was tried without positive results. Neither Sheffield's histological and cytological studies (1950)† nor Nutman's physiological work (1950) gave any help in elucidating the disease problem. The most convincing evidence against the virus theory, however, was provided by the successful grafting experiments carried out by May, although the clove is exceptionally difficult to treat in this way. Young, actively grown seedlings take many months, even when inarched, to form unions. May (1949), however, even succeeded in cleft-grafting scions from diseased trees directly to healthy stocks. None of these transmitted the disease and all are at present healthy some years after the death of the trees from which they were derived.

Towards the end of 1950, the mycological investigations began to show promise and Nutman and Roberts were able, soon after, to demonstrate that Dieback is caused by the invasion of wounds, usually caused by harvesting operations, by the fungus *Cryptosporella eugeniæ* sp. nov. Nutman and Roberts (1952). This fungus can also attack the main stem of young trees and, when girdling is complete, cause them to die with symptoms indistinguishable from those of Sudden death.

Sudden death was found to be invariably associated with a *Valsa,* again a new species. Nutman and Roberts (in Press) later succeeded in proving that this fungus was pathogenic to mature clove trees, that seedlings were immune and that saplings were resistant. They demonstrated experimentally that its spores could initiate invasion of the absorbing roots of mature trees, and that, from these it can invade first the fibrous roots and later the main roots. A similar state of affairs can be observed in trees in the early stages of Sudden death, *Valsa* being found, at this stage, only in the peripheral parts of the main roots and in the finer ramifications of the root system.

The "Slow Decline" of young clove trees was also investigated: this condition is now increasingly common where young trees have been interplanted between the rows of dead and dying mature trees, or in areas previously devastated by Sudden death. Slow Decline was found to be absent in those few plantations which were, so far as could be ascertained, planted on virgin land, or where new plantings were made in old "Dieback" areas. Campbell's description of the root-rot associated with Slow Decline (his "immature Dieback") is substantially correct, and this condition, in its most typical form, is extremely similar to Sudden death but on a different time-scale, the death of the tree usually taking place several years after the first appearance of symptoms. From the roots of these young diseased trees Nutman and Roberts were able to culture the same species of *Valsa* which is consistently associated with the Sudden death disease, the fungus being absent from the roots of healthy saplings. They concluded that Slow Decline is a symptom-expression of *Valsa* attack when the juvenile resistance of the sapling is beginning to break down.

Research on the two major diseases of the clove tree has now reached a stage when only long-term technological experiments, based on the recommendations of the Clove Research Scheme, can, in the case of Sudden death, provide information on which successful control and rehabilitation might be achieved. Such

* Mr. F. C. Bawden, M.A., F.R.S., Deputy Director, Rothamsted.
Dr. W. Hall, Director, Commonwealth Bureau of Entomology.
Dr. H. Martin, Long Ashton, Bristol University.
Dr. H. H. Storey, C.M.G., F.R.S., Deputy Director, E.A.A.F.R.O.

† Sheffield observed abundant fungal hyphæ in the roots and collars of diseased trees, and also in highly suspect trees where "the fungi were confined to the roots and were no more in quantity than those found in healthy trees". We now know that in any stand of even-aged trees where Sudden death is epidemic, the smaller roots of apparently healthy trees are often already infected with *Valsa*. That Sheffield misinterpreted her evidence is shown by her statement that "The total hyphæ in the advanced suspect would seem to have been greater than in the healthy roots only because a *greater proportion of the roots die back*". (Italics ours.)

experiments are properly the responsibility of the Department of Agriculture. As regards Dieback, however, the work of the Clove Research Scheme has demonstrated, on a plantation scale, that this disease can be readily controlled and is preventable. Thus, the present Department of Agriculture has a more solid basis on which to work than had any of its predecessors.

In reviewing the causes which have led up, possibly, to the loss of a major industry, it is interesting to note that, of all those administrators, agriculturists, and scientists who have been concerned in Zanzibar with the clove industry and mentioned in this study, only one seems to have emerged with undiminished credit, namely McClellan. He, for nearly 20 years, struggled vigorously to secure scientific advice for the clove industry. Credit must also be given to the Colonial Office advisers, who prevented the closing down of the Agricultural Department in 1912, who arranged for Welsford to be appointed, whose recommendations led to Campbell's appointment, and who initiated the present Clove Research Scheme. In fact, such scientific work as has been done on the clove tree seems to have been due, almost entirely, to them.

On the other side of the ledger, pride of place must be conceded to the Supervising Member of Council who so successfully thwarted McClellan in his efforts to get mycological advice. McClellan's successor, Kirkham, who stopped Welsford from doing plant pathological research and who, on his own showing, did not believe in active scientific work, or in the importance of plant disease, is also not without his share of responsibility.

Campbell's inability to realize the inconclusive nature of his own work has had far-reaching and disastrous results; his assertion that it was safe to replant between dead and dying trees is still having its repercussions. Further, his statement that he had disproved the theory of a fungal causation, and the uncritical acceptance of this statement by so many, resulted in a profound physiological bias against this theory; so strong was this bias, in fact, that when it was first suggested that *Valsa* might be implicated in Sudden death, the news, except at Kew, was received with considerable scepticism, and in Zanzibar, even now, is disbelieved in a few influential quarters.

The present increasing and unchecked death-rate of the clove trees in the Protectorate is a challenge to the Administration and the Department of Agriculture. One of their most difficult tasks will be, by continuous propaganda, to change the habits of thought of the plantation owners, Arab, African, and Asiatic. The larger proportion of the trees in the Protectorate is still owned by Arabs, whose conservatism is intense*; and who have never adapted themselves fully to the change in condition brought about by the abolition of slavery. They are not hard workers, and being, as Tidbury (1949) put it, much addicted to "town life and social activities of an unremunerative nature" tend to become absentee landlords, paying little attention to their plantations and selling the crop on the trees to a middleman whose sole object is to make the maximum profit irrespective of damage. In lack of good management and gross neglect of plantations, however, there is little to choose between the three main racial groups of growers, although there is the occasional enlightened exception. It cannot be said that the Government plantations, or those managed by the Public Trustee, have always set a good example.

At present more than half the mature clove trees in Zanzibar Island are dead, and the disease is progressing rapidly; in 1950 there were over 2,000 separate outbreaks in Pemba Island and these are increasing rapidly both in size and number; many, perhaps most, of the young trees in Zanzibar Island are likely to die of Slow Decline, and Dieback is both widespread and increasing in both islands. Even so, it may not yet be too late to save the clove industry in Pemba and, perhaps, to re-establish another in Zanzibar. But there is no time for delay.

In conclusion we would like to express our thanks to Mr. A. K. Briant, the present Director of Agriculture, and to his predecessor, Mr. O. S. Swainson, for giving us access to departmental files and records; and to Mr. G. E. Tidbury, Senior Agricultural Officer, who has taken great interest in this account and who has provided us with many important

* As an example of this, a local paper, *Al Falaq*, in its issue of 16th July, 1952, writes, approvingly, of the Arab plantation owners " . . . they have no faith in experimental treatment to check [*sic*] the 'sudden death'; their credence is that death is a natural phenomena [*sic*] which may strike human beings, animals, and trees". Earlier in the same article, criticizing "European ideas brought by experts" the paper states that these have had "no results except that those who were once rich agriculturists are now striken with poverty due to the death of their clove trees".

facts. It is with pleasure that we acknowledge our indebtedness to Dr. R. M. Nattrass, Senior Pathologist to the Kenya Department of Agriculture, who, in the early stages of our investigation of the fungal hypothesis visited Zanzibar at our request, and whose wide experience of mycological problems and plant pathological techniques was of very great assistance to us. He has since consistently been both stimulating and helpful. We also wish to thank Dr. H. H. Storey, C.M.G., F.R.S., for valuable and constructive criticism of our manuscript.

REFERENCES

Briant, A. K. (1946). Survey of matters affecting the clove industry in Zanzibar.*

Campbell, A. H. (1940). Report on the Sudden death disease of clove trees in the Zanzibar Protectorate.*

Campbell, A. H. (1942). Memorandum on the dieback of clove trees in Zanzibar.*

Dowson, W. J. (1914). Report on my visit to Zanzibar and Pemba.*

Fitzgerald, W. W. A. (1892). Report on the spice and other cultivations of Zanzibar and Pemba Islands. Foreign Office 226, London.

Glover, J. (1939). Report on a visit to Zanzibar in connexion with the Sudden death disease of the clove trees.*

Kirkpatrick, T. W. (1932). Report on the economic status of the so-called clove chafer in Zanzibar.*

May, W. B. (1949). Horticultural work with the clove tree in Zanzibar. Gard. Chron. CXXV, 178–179.

McClellan, F. C. (1922). Memorandum by the Director of Agriculture.*

Nutman, F. J. (1950). Studies of the clove tree. 3—The effect of the Sudden death disease on water relations. Ann. appl. Biol. 37, 584–590.

Nutman, F. J., and Roberts, F. M. (1952). Two new species of fungi on clove trees in the Zanzibar Protectorate. (In Press.)

Nutman, F. J., and Roberts, F. M. (1952). Severe Dieback of clove trees in the Zanzibar Protectorate. (In Press.)

Nutman, F. J., and Roberts, F. M. (1953). The relation of *Valsa eugeniæ* sp. nov. to the Sudden death disease of clove trees in the Zanzibar Protectorate. (In Press.)

Nutman, F. J., and Sheffield, F. M. L. (1949). Studies of the clove tree. 1—The Sudden death disease and its epidemiology. Ann. appl. Biol. 36, 419–434.

Nutman, F. J., Sheffield, F. M. L., Swainson, O. S., and Winter, D. W. (1951). The Sudden death disease of clove trees and its economic and agricultural significance. Emp. J. Exp. Agric. XIX, 145–159.

Pim, A. (1932). Report of the Commission appointed by the Secretary of State to consider and report on the financial position and policy of the Zanzibar Government in relation to its economic position. Zanzibar.

Sheffield, F. M. L. (1950). Studies of the clove tree. 2—Histology with special reference to the Sudden death disease. Ann. appl. Biol. 37, 23–45.

Tidbury, G. E. (1949). The Clove Tree. London, Crosby Lockwood.

Troup, R. S. (1931). Report on clove cultivation in the Zanzibar Protectorate. Zanzibar.

Welsford, E. J. (1922). The mycologists annual report.*

Wigg, L. G. T. (1937). The clove plant, *Eugenia aromatica ca L.* Zanzibar.

* Denotes that the reference is in the files of the Department of Agriculture, Zanzibar.

THE SORGHUMS AND SORGHUM IMPROVEMENT IN TANGANYIKA

By H. Doggett, Department of Agriculture, Tanganyika

(*Received for publication on 4th March,* 1953)

The sorghums are grasses which have been cultivated for their grain since ancient times in Africa and Asia, and they probably originated in North Africa. They grow well on a wide range of soil types, and will thrive on a lower rainfall than maize, being much more drought resistant. At one time they were widely cultivated in Tanganyika, but have now been replaced in many parts by maize. This has had an unfortunate effect on food supplies in areas where the rainfall is uncertain or low, as sorghums yield much more consistently than maize under such conditions.

The sorghums have a very efficient root system, which ramifies throughout the soil and occupies it fully. In the early stages the roots are mainly in the surface layers of the soil, but in mature plants they may reach a depth of from 4 to 6 ft., with a lateral spread of 3 to 4 ft.

The stems are solid, dry and pithy, or sweet and pleasant to chew. The green parts of the plant can be a good fodder, but contain a form of cyanide, which may increase during a period of drought sufficiently to poison live-stock. Many varieties tiller at the base, while in some, side branches are produced from the nodes of the main stem. There is a wide range of sorghum types, varying in height from 3 to 15 ft., and in length of maturity from 3 to 7 months. The height is governed by the number of leaves and the length of the internodes, while the length of maturity is correlated with the number of leaves produced before the plant flowers. For this reason, a plant with very short internodes may be only 4 ft. in height, yet may take as long to mature as a plant 12 ft. high which has long internodes. The height of a plant which matures in 3½ months may be as much as 7 or 8 ft., although the majority are about half this figure. Most early-maturing plants are of short stature, but some short plants are late or very late in maturing.

In certain varieties the lower part of the panicle remains enclosed by the top leaf sheath (the boot), while in others the panicle is carried for some distance above the boot. The panicle itself shows great variation, from a very dense "club", tightly packed with grain, to an open "grass-like" panicle with the grain scattered on long branches. It is usually carried erect, though in some sorghums the stem may be recurved above the uppermost internode, so that the panicle is partially or completely inverted (Goose-necked).

The spikelets flower from the top of the panicle downwards, and are mostly fertilized by pollen from the same spikelet, or from another spikelet in the same head, although as many as one-quarter may be fertilized by pollen from other plants, so that it is difficult to maintain pure varieties of sorghum when several varieties are grown near one another. Wind pollination is usual, but at times bees work the sorghums for pollen. In nearly all sorghums each spikelet produces one grain only, but in a few varieties twin grains are found in some or all of the spikelets. Sometimes the ripe grain is tightly enclosed by the glumes of the spikelet, and such varieties are unpopular as they are difficult to thresh.

The grains of the numerous forms of sorghum show great variation in size and in shape. The colour may be white, yellow, or shades of brown and red. The most palatable varieties have grains which are white through-out while the brown- or red-grained sorghums often contain tannins which are bitter. In some areas a brown, slightly bitter grain is preferred for food, but the very dark grains are grown only for brewing. The texture of the grain may be soft and starchy, or corneous throughout, while many intermediate forms exist which have a corneous layer wholly or partially surrounding a soft, starchy centre. The grain of some varieties has a waxy endosperm, from which a special starch similar to tapioca can be produced. Sorghum flour ground in a roller mill is much preferred to that produced in a hammer mill. The flour is eaten by some tribes only when arduous work is being done, such as the preparation of land for planting.

Pests and Diseases

The major pests of sorghum are stalk-borer and Atherigona, the central shoot fly. The former may do great damage, and much reduce yields, being more abundant in some years than in others. Atherigona is bad in some areas, but does not often attack plants early

in the season. As it attacks only young plants, early plantings are usually safe by the time it appears, but late plantings may be so damaged that they give little or no yield.

There are several leaf diseases of sorghums, but in Tanganyika indigenous varieties seldom suffer great damage, although some imported types are severely attacked. Grain smut can cause great loss, the panicle producing silvery sacs of black spores instead of grain, but it can be partially controlled by dusting the seed before planting with surphur, agrosan, or other fungicides. Certain varieties are resistant to the smut. Mildew may damage the grain if it ripens under wet conditions, and types with very compact heads suffer most, as the inside of the panicle dries slowly.

Witchweed (Striga) severely reduces the yield and vigour of the plants which it attacks. It is a semi-parasitic plant, the seeds of which may lie dormant in the soil for many years, germinating when stimulated by a secretion from a sorghum root. The young witchweed plant roots fuse with those of the sorghum, and it grows at the expense of its host, doing much damage to the sorghum even before appearing above ground. Once Striga does appear, growth is rapid, and flowering begins about three weeks later, very many small light seeds being produced and distributed over the soil. Control can be effected by uprooting the witchweed before it has flowered, or by trap cropping by planting sorghum and ploughing it in before the witchweed growing on it has flowered. Rotations can also be useful, as some crops (e.g. cow-pea, cotton and sunflower) will germinate witchweed seed, but the Striga plant cannot mature on them. However, none of these methods is properly employed by African cultivators, and certain areas are now so heavily infested with witchweed seed that sorghum-growing is not worth while.

Birds should also be included as a major source of crop loss, becoming increasingly troublesome in native *shambas*, as African children now go to school whereas previously they were employed to scare birds from their parents' crops. The birds prefer white grains, but will take brown ones where no choice is available.

Sorghum Improvement

Methods

Selection within a variable population of a crop is the plant breeder's basic method; plants are chosen which appear to have the desired combination of characters, and are harvested separately. Progeny rows are planted, each row being the progeny of one selected plant; the individual plants in the rows are self-pollinated, in the case of sorghum by bagging the heads, and further selections taken from among these self-pollinated plants; from these, new progeny rows are grown, and this process is repeated until rows of plants which are uniform for the required characters are obtained. These are new varieties, which are multiplied, tested in variety trials, and the best of them issued to the grower. In sorghum, three generations of progeny rows are often required before reasonably uniform plants are obtained and the process can frequently be continued with advantage for many more generations. The breeder normally commences work with a very large number of initial selections, and culls his material during the progeny row stages, discarding plants with undesirable characters until only a few of the best remain to go into variety trials.

The population of the crop in which the plant breeder is selecting may not contain the combination of characters which he requires, or some characters may be missing altogether. It is then neceessary to hybridize, in order to produce a fresh population which does contain combinations of the required characters, in which he can select. The basic method remains that of selection followed by progeny rows, and the sole object of hybridization is to produce more variability, so that the breeder can obtain selections of the desired type. A useful development of hybridization is the backcross method, in which repeated crosses are made. A good variety lacking in one character is chosen as the recurring parent, and another variety which possesses that character is used as the other parent for the first cross only. Plants with the character in question which appear in the progeny of the first cross are selected and crossed again to the recurring parent. The progeny of this second cross are examined, and suitable selections possessing the required character are backcrossed again to the recurring parent. This process may be continued until a new variety is produced which is indistinguishable from the recurring parent variety, except that a new character has been added. In other cases one or two backcrosses are sufficient for the breeder's purposes, and in such a case, a population is obtained with many plants having many of the characters of the recurring parent, and a number of them will also possess the

character which was selected for in making the backcrosses. Selections are taken from this population, and progeny rows are grown.

The breeder will often collect many varieties of the crop with which he is working from all over the world. Plants are usually well adapted to the conditions in a place where they have been growing for many years, and it is seldom that an importation will grow as well as an indigenous variety, as the weather conditions and pattern of attack by pests and diseases are likely to be different. Imported varieties can often be useful as parents, however, in crosses with indigenous types.

Mention should also be made of the "panmixia". A panmixia is obtained by planting together many varieties with many different characters, and allowing them to hybridize freely. A sufficiently large random sample of seed is taken at each harvest to ensure that none of the characters is lost, and this seed is planted again as a mixture in the following season. Owing to free hybridization in the panmixia, recombinations of characters are occurring all the time, and it becomes a valuable source of selections. The breeder can adjust the ingredients of a panmixia which he makes up, and can keep it going with little effort; taking selections from it when he sees that plants which he requires have been produced in it.

Sorghum Improvement in Other Countries

Much breeding work on sorghum has been done in the United States since the crop was first grown there some 70 years ago, and great advances have been made during the past 30 years. The average acreage grown for grain annually between 1940 and 1945 in the United States was 6½ million acres, yielding an average of 17 bushels per acre. The development of short-strawed types suited to combine harvesting has speeded the rate of harvesting tenfold, and the breeding of early-maturing types has greatly extended the sorghum-growing area. Grains suitable for industrial uses (mainly starch and alcohol production) and for stock-feed have been developed, but relatively little attention has been given so far to sorghum as a human food. Resistance to some of the pests and diseases has been obtained, and varieties are now available for the main sorghum-growing regions of America, bred specifically for the conditions in each area.

American, South African and Indian workers have produced much useful information on the methods of breeding sorghums and the inheritance of plant characters, and in South Africa a witchweed-resistant variety called Radar has been bred.

Sorghum Improvement in Tanganyika

The breeding of sorghums has recently been commenced in Tanganyika. A long list of desired types could be prepared, and of these the types most urgently required are early-maturing sorghums with grains which store well, varieties which are less susceptible to bird damage, sorghums with a degree of resistance to infestation by witchweed, and dwarf types suitable for combine harvesting.

The indigenous long-term sorghums include many that are very satisfactory, and improvement work on them is not a pressing need. Most of them have medium to soft grains, which store poorly, and are consumed or used for brewing in the current season, a reserve being kept, well mixed with ash, for planting the following year. A number of sorghums with hard, flinty grains are grown as well, and these used to be regarded as a reserve, which would keep for several years with a little care. Most of the latter are late or very late in maturing, and are rather light yielders.

Early-maturing sorghums (3 to 4 months from planting to harvest) would be very valuable in the African economy when food is in short supply, and in many seasons would be a useful supplement in the lean period between planting and harvesting the main, long-term crop. The hopes that they would supply a quick harvest, if these crops planted with the first rains had failed, are unlikely to be realized when central shoot fly is serious.

Early-maturing types tried out in Tanganyika have shown promise, but all which yield well have soft grains which store very badly, often becoming infested with weevil and larvæ of moths before harvest, and proving very difficult to carry on from one season to the next.

Breeding for Grains Resistant to Weevil Attack

The problem of obtaining a short-term sorghum which will store well depends first on determining the grain characters which affect storage. Tests were done by enclosing 100 grains of sorghum in mosquito net bags, a separate bag for each variety, with sufficient replications, and burying these bags in a bulk of weevily grain. The number of grains damaged was counted every fortnight, and a satisfactory correlation between the rate of weevil damage and the thickness of the

corneous layer in the endosperm was obtained. This character is a simple one to select for in the field. From the beginning it seemed probable that the corneous layer was important, and breeding for this character was begun before a relationship had been proved.

Selections for grains with a corneous endosperm were made in the early-maturing sorghums available, and for earliness in the indigenous late-maturing varieties which store well. None of the very large number of selections made was satisfactory, the majority being discarded because of undesirable field characters, such as very small heads or tight glumes. Hybridization was therefore tried, two good early-maturing varieties being used as recurring parents. (B.C. 27 from the Belgian Congo, and Dobbs from Kenya.) These were crossed to Wiru (indigenous, late maturing, with a corneous endosperm). In the second generation from the cross, early-maturing plants with the Wiru type of grain appeared, but all had very poor heads. The first backcross was done, and material segregating in the second generation from the first backcross B.C. 27 (B.C. 27 x Wiru) looks very promising. A second backcross has also been made, but one backcross is likely to be sufficient. Other late-maturing parents have also been used, including Msumbiji from Lindi and Belko from West Africa. The same situation arose in the B.C. 27 x Msumbiji crosses, the first cross yielding poor material, the first backcross looking a great deal better. Three generations of selfing will probably be required before new early-maturing sorghums with grains that will store well are ready.

Birds

Bird damage presents a difficult problem: the pattern of bird attack varies a good deal from place to place, but the most serious trouble is caused by large flocks of Quelea which appear towards the end of the rains. In some areas, bird damage is almost confined to the havoc wrought by Quelea late in the season, and the resident population of grain-eating birds earlier in the season is low. In such places, an early-maturing sorghum planted at the beginning of the season will harden its grain before the large flocks of Quelea have appeared, and will then be left alone. In other areas where there is a good deal of scrub, there is a fairly large resident population of grain-eating birds, including small groups of Quelea, and in these areas earliness of maturing is of no benefit whatever in reducing bird damage.

Sorghums with compact, inverted heads (goose-necked) suffer less bird damage than erect types with open heads, the grain on the underside of the panicle remaining undamaged. Awns in sorghum are neither long enough nor strong enough to give complete protection against birds, but they may make the sorghum somewhat less attractive. It is interesting to note that almost all sorghum varieties received at Ukiriguru from India have been goose-necked, with compact, or very compact, heads, and often with bristly awns. Appropriate crosses have been made with Ng'hollongo (indigenous, late maturing, compact inverted head) and Nandayal Poona (an Indian sorghum with a fairly compact head and a bristly awn) on to B.C. 27 and Dobbs, in order to bring these characters into the early-maturing population.

Mention has already been made of the birds' preference for sweet white grains rather than the brown and bitter ones. It is of little use breeding for this character, as few Africans like the bitter grains. Dr. Karper has sent from America recently two sorghums the grain of which is said to be unpalatable when green, but to become palatable when ripe. These may help in breeding for resistance to birds.

Witchweed

One aspect of the attack on witchweed is the breeeding of resistant varieties. Field counts covering several seasons and different districts in the Lake Province show that Dobbs carries many less witchweed plants above ground than local sorghum varieties, while still maintaining a good yield. Selection work within Dobbs is in progress, and the use of Dobbs as a recurring parent makes it probable that new varieties being bred will also have a degree of witchweed resistance. The species of witchweed to which Dobbs shows some resistance is *Striga hermonthica*, which is important in many parts of the Territory. In other areas *Striga asiatica* is more important, and there is no reason why a plant which is resistant to *Striga hermonthica* should also be resistant to *Striga asiatica*. Resistant types from South Africa and India have been bred for resistance to *Striga asiatica*: varieties tried do not yield well here, but may prove useful as parents when work is begun on the *Striga asiatica* problem.

Sorghums for Mechanical Harvesting

To the African peasant, the height of the plant, the exsertion of the head from the boot, tillering, and branching from the main stem are

not important characters. Sorghums for combine harvesting, however, must ripen evenly, so tillers and branches are bad characters, as the heads borne on them ripen after those carried on the main stem. The height of the plant should not be more than 4 ft., the head should be carried well clear of the top leaf so that too much trash is not taken into the machine, and the stem should not remain juicy after the grain has ripened sufficiently to be harvested. Length of maturity, and grain and panicle characters are important, but witchweed and stalk-borer can be controlled by cultural practices where large areas of grain are being grown with the aid of machinery.

American workers have produced good combine types, some of which have been tried in Tanganyika. Considering that they were bred for American conditions, a few have grown well in certain places, particularly at Kongwa, but it will be necessary to breed types locally in Tanganyika, as there are many areas where the American varieties have been a failure. Selection work to this end has been started at Ukiriguru, and in addition three of the American types, Oklahoma 44/14, Martin, and Dwarf Shallu, have been crossed with local varieties. The American varieties will be useful in the production of combine types in Tanganyika, and United States plant breeders have been very generous in making available the products of many years of their own work.

The variety Korgi from the Sudan has a grain which is several times the size of the local grains, and can be handled like maize in preparing food by African methods. This has been used as a parent in crosses. Apart from the fact that it may enable better-yielding sorghums to be bred, it is a very attractive character to the African cultivator, and may be of some assistance in marginal areas where it is hoped to encourage the growing of sorghum rather than maize.

A good degree of resistance to grain smut exists in some sorghums, and crosses are being made to incorporate this in the varieties now being bred. Such characters as yield, ease of threshing, vigour, and resistance to leaf diseases are of course taken into account in all the selection and breeding work in progress. Stalk-borer is responsible for great losses, and although it is possible that some degree of resistance to this pest exists, this problem cannot be tackled at Ukiriguru at present.

Plant-breeding has resulted in great improvements in many grain crops, and there is every prospect that such work will prove to be of value to the development of sorghum-growing in Tanganyika. Great strides have been made in the breeding of sorghum in America, resulting in considerable expansion of the area under sorghum there. Plant-breeding is a slow process, but there is every reason to expect that the work on this crop recently commenced in Tanganyika will yield profitable results in due course.

LITERATURE

Some of the general literature on sorghum and sorghum-breeding is listed below:—

BOOKS

Snowdon, J. D. (1936). The Cultivated Races of Sorghum. Alard & Son, London.

Hector, J. M. (1936). Introduction to the Botany of Field Crops. Vol. I—Cereals. Central News Agency, Ltd., Johannesburg.

PAPERS—GENERAL

Ball, C. R. (1910). The Breeding of Grain Sorghums. Amer. Breeders' Mag., 1: 283–293.

Evelyn, S. H. (1951). Sorghum Breeding in the Sudan. World Crops, *3* No. 2.

Karper, R. E. (1946). Possibilities for Industrial Uses of Grain Sorghum. The Chemurgic Digest, February, 1946.

——and Quinby, J. R. (1946). 984. Progress Report—Texas Agric. Experiment Station—A. & M. College of Texas.

—— (1946). The History and Evolution of Milo in the United States. Jour, Amer. Soc. Agron. 38, No. 5, 441–453.

—— (1946). Successful Sorghums. Southern Seedsman, March, 1946.

—— (1947). Sorghum—Its Production, Utilization, and Breeding. Econ. Bot., 1, No. 4, 355–371.

—— (1947). New Varieties of Sorghum. 1064 Progress Report, Texas, Agric. Experiment Station, A. & M. College of Texas.

—— & Kramer, N. W. (1951). 1367 Progress Report, Texas Agric. Experiment Station, A. & M. College of Texas.

Martin, J. H. (1936). Sorghum Improvement, U.S. Dept. of Agric. Year Book.

Swanson, A. F. (1949). Recent Developments in Grain Sorghum Production by Plant Breeding Methods. Agron. Jour. *41*, No. 5, 179–181.

—— & Laude, H. H. (1933). Sorghum Production in Kansas. Kansas Experiment Station Bull. 265.

—— (1942). Sorghums for Kansas. Kansas Agric. Experiment Station Bull. 304.

For more technical papers, consult "Plant Breeding Abstracts" (Commonwealth Agricultural Bureaux), under the following authors:—

Ayyangar, Ayyar: Ayyangar, G. N. Rangaswani: Conner, A. B.: Karper, R. E.: Laubscher, F. X.: Quinby, J. R.: Ramanathan, V.: Reed, C. M.: Sieglinger, J. B.: Stephens, J. C.: Swanson, A. F.: Vinall, H. N.

LAND USE AND TSETSE CONTROL

By E. Aneurin Lewis, East African Tsetse and Trypanosomiasis Research and Reclamation Organization

(*Received for publication on 28th April*, 1953)

The purpose of this article, which was submitted as a memorandum to the East African Advisory Council on Agriculture, Animal Industry and Forestry, in January, 1953, is to show by examples what has been achieved in East Africa by applying the results of research to the reclamation of land infested by tsetses. It also indicates generally the basic information which is required in order to understand more fully how the different species of tsetse flies live and how they contract and transmit infection by trypanosomes, and what needs to be investigated to find still more effective and economic methods of controlling the vectors and the disease. It raises the problem of land use in connexion with tsetse reclamation schemes and the control of trypanosomiasis in man and animals; and suggests a number of subjects on which further information is required to hold the land and to establish a sound basis for its proper development.

Many thousands of square miles of land infested by tsetse flies have been reclaimed by Tsetse Control Officers of Uganda, Tanganyika and Kenya, and as the result of experiments by the East African Tsetse and Trypanosomiasis Research and Reclamation Organization since the end of the world war in 1945. Threatened advances of fly belts in some areas have also been dealt with satisfactorily, at least for the time being; and fly populations in other areas have been reduced to extremely low figures—or they have been eliminated—by the application of insecticides by the Colonial Insecticides Research Unit operating alone or in conjunction with territorial and inter-territorial teams.

These and earlier achievements demonstrate that fly-infested land can be released for the use of man and stock. The fact that reclamation was undertaken in the cases given in the annual reports of the Tsetse Control establishments in East Africa presupposes that the land already infested or in imminent danger of infestation was required for use either for the production of crops, for grazing of farm animals, for mixed farming or for protection against human sleeping sickness and the spread of animal trypanosomiasis. That is, tsetse control is merely a step towards a greater purpose—the beneficial use of the land, the conservation of its fertility and continuous production.

While the first step of fly control has been successful in many instances, it has not always been so. Some species of tsetse present tougher problems than others, and even one and the same species may be more difficult to deal with in some areas than in others. Much preparatory work is necessary in practically every district in which anti-tsetse measures are to be undertaken. This comprises reconnaissance followed by a detailed survey of the fly distribution and breeding sites, a study of the woody vegetation and general observations on the topography and soil, and of the animals which form the source of food for the fly. On the basis of this information a plan of anti-tsetse operations is drawn up and, in due course, put into effect. Observations on the fly situation are kept on during the operations and, by employing methods indicated by research workers from time to time, the progress of the work can be assessed with a high degree of precision and accuracy, so that modifications and adjustments can be introduced if necessary.

Fact-finding over a reasonably large area—or survey—is the first phase of a tsetse project. The second phase is the formation of a plan and programme of work. The third is management in accordance with a plan and subsequent adjustments. Each phase is covered closely by a European officer appropriately qualified and instructed.

The chief anti-tsetse measures are—

(i) the control of game animals which form the source of food of the commoner and most widely distributed species of tsetse;

(ii) the clearing of bush (the woody vegetation) which comprises the habitats of the different species and which are essential for the shade and shelter all species require;

(iii) the application of the modern insecticides, either in the form of aerial sprays or ground sprayings;

(iv) the judicious use of fires to maintain open woodland in the absence of farm stock;

(v) the maintenance of a human population in sufficient density to prevent excessive growth of bush and to discourage game.

Game Control

It has been shown in Southern Rhodesia, Uganda and Tanganyika, for example, that the systematic destruction of game animals (usually restricted to the larger species—in size from that of a reed buck upwards in the experiments carried out by the East African Tsetse and Trypanosomiasis Research and Reclamation Organization at Shinyanga in Tanganyika) leads to the disappearance of *Glossina morsitans* which is responsible for the infestation of about 190,000 square miles of the 207,000 square miles of fly country in Tanganyika, and for just over 8,000 square miles out of approximately 24,000 square miles of infested land in Uganda. This species occurs only in a very small area in the north-west of Kenya on the Oropi River which rises in Karamoja in Uganda. By far the largest areas of land which have been reclaimed in East Africa appear to have been freed from *G. morsitans* by the shooting of game.

The game-destruction experiments over 600 square miles at Shinyanga also resulted in the eradication of *G. swynnertoni* which is common in the north-east of Tanganyika and in the adjoining Masai country of the Narok district, Kenya. It may be of interest to know that effective fly control by this method at Shinyanga was achieved in approximately five years. The density of animals was originally in the neighbourhood of about ten to the square mile (Potts and Jackson, 1952). The result was achieved at a cost of £50 per square mile (or Sh. 1/56 per acre). It would have cost very much more had not the blocks of bush been isolated from the rest of the fly belt in the area by wide and long strips of treeless country, thus protecting the reclaimed land from reinvasion by game and from reinfestation by tsetses. Nevertheless, constant watch has to be maintained until the land is taken over for occupation, the removal of tsetse habitats by settlers, and the development of the area which will also tend to keep the game away permanently.

In Uganda, about 4,500 square miles have been reclaimed mainly from *G. morsitans* by game control between 1946 and the end of 1951.

The evidence from Uganda, Tanganyika and other parts of Africa supports the view and experience of workers in Southern Rhodesia that the destruction or expulsion of game leads to the disappearance of *G. morsitans*. This species of tsetse was eradicated from about 10,000 square miles of Southern Rhodesia in the period 1925–1933. It was held along a front of little more than 380 miles for the ten years between 1940 to late 1950. In the last year or two, however, the front has been broken in some sections. The flies have returned, causing considerable losses in areas which had not been cleared of bush and where suitable habitats for *G. morsitans* had remained untouched. It is clear that unless the gains achieved against this fly by game control are consolidated by supplementary bush-clearing and full utilization of the land reclaimed, or by constant vigilance on a long front for an indefinite period, there will always be a danger of reinfestation and of its consequent disasters. The activities of man tend to disturb and frighten most game animals, which often leave the area for some time. The departure of the game frequently affects the fly population, which drops considerably, only to recover its previous level when the game returns on the cessation of man's activities.

Bush-clearing

Whereas game is the main source of food of tsetse and of their infection with the trypanosomes affecting stock, different plant communities make up the habitats where different species of tsetse find the necessary environmental conditions favourable to their survival and multiplication. Research workers have from time to time suggested routine methods of surveys, regular patrols and analysis of fly catches which have been employed in determining the localities and the extent of these habitats, and the purpose for which definable vegetation communities are used by the fly. Thus, studies of where and how the flies live contribute to less drastic methods than the wholesale destruction of bush as an anti-tsetse measure. Only on very rare occasions are all the trees and shrubs destroyed in the case of bush-clearing for the control of tsetse. It is now possible in the case of *G. morsitans*, *G. swynnertoni* and sometimes *G. pallidipes*, to restrict the destruction of vegetation to relatively small localities of a large area. Only certain plant communities forming the perpanent habitats of the flies are removed. This method of bush-clearing—discriminative clearing—was successfully carried out by the Tsetse Research Department, now absorbed by the

East African Tsetse and Trypanosomiasis Research and Reclamation Organization, against *G. morsitans* in an area of approximately 600 square miles near Abercorn, and of about 100 square miles at Tabora. *G. swynnertoni* (but not *G. pallidipes*) has been eradicated from a 50-square-mile block of bush (Block 11) at Shinyanga, at least 118 square miles on the Ukerewe Peninsula by the territorial department, and some 300 square miles freed from *swynnertoni* and *pallidipes* in south-west Musoma. *G. pallidipes* has also disappeared from about 100 square miles of pasture land in the Kwale district, Kenya, and a smaller area near Kilifi. The extent of bush-clearing in these areas is from 2 to 15 per cent of the land previously rendered unavailable to cattle and often to man. Selective clearing, by which is meant the removal of certain species of trees and shrubs, has been employed successfully against *G. pallidipes, G. palpalis, G. austeni* and *G. brevipalpis* especially when adopted in conjunction with discriminative clearing of tsetse barriers.

While the percentage of bush cleared in schemes successfully carried out to date has been low, there is much yet to be done to discover still more effective methods to reduce the amount and cost of bush-clearing as an anti-tsetse measure. The control of *pallidipes, palpalis* and *longipennis,* for instance, is far from satisfactory.

The cost of bush-clearing is high although, when calculated in relation to the economic value of the acreage released for grazing in some cases or areas freed from disease, the cost per acre is frequently very low indeed. It is noteworthy that in Tanganyika free communal or tribal labour features quite commonly n accounts of reclamation schemes. Reports from Tanganyika refer to turnouts of 900 men; of 100,000 man/days becoming available; to 20,000 having turned out in one year (1942), and tribal labour putting 30,000 man/days in the area (Ukerewe). In Kenya and Uganda, on the other hand, it is rare that a sufficient turnout can be obtained nowadays, even at relatively high wages and rations, considering that the land which is to be, or is being, reclaimed belongs to the tribe from which labourers are usually recruited.

In most fly-infested areas, however, the density of the population is extremely low. The villages are normally far away from the affected area; and the people are not particularly interested in reclaiming the land, which they and their forefathers abandoned either as useless or as dangerous to man and beast. It is in such cases that bush-clearing by machinery may ultimately have to be adopted. The advantages of mechanical clearing are many when labour is difficult to obtain or manage, the turnout is small and the quality poor. Machines appear to cost more than human labour. In a reclamation project at Arusha, in Tanganyika, involving an area of 500 square miles of Masai grazing lands (in 1945–1946) bush-clearing by bulldozers cost Sh. 50/77 per acre in comparison with manual labour at Sh. 8/47 per acre (du Frayer, 1951). The achievements of bush-clearing by hired bulldozers at Makueni in Kenya and in the Masai Reserve (near Arusha) in Tanganyika are of interest in directions other than those of effective tsetse control. The fears entertained at one time by some observers, that these machines remove the top soil and grass and would almost certainly be followed by loss of soil fertility and erosion, were soon dispelled. The ground quickly recovered its grass cover and grew more profusely and thickly than before. There was no sign of erosion; in fact, the danger of erosion was considerably less than before.

Hornby (1941) writing of "the usual native (and European) method of herding stock" states that "the owner turns his animals into open thicket and savannah and expects them to get their living there. If their numbers are more than a few the usual results are that the bush gets thicker, carrying capacity is lowered, soil erosion is engendered, danger from vermin and theft increases and, in certain conditions, encroachment by tsetse is encouraged". He states also that "the aim of the pastoralist is the maintenance of open grassland—a form of vegetation which, by itself, cannot support any species of tsetse" and "since the essence of much tsetse reclamation is the substitution of grasslands for woodlands, on the maintenance of pastures may depend both the value and the permanence of clearing".

It seems that discriminative clearing of bush to eradicate tsetse as an essential step of reclamation must be followed by further clearings for the extension and improvement of grasslands. Staples (1941) has stated that it has been assumed that while anti-tsetse clearing may be effective in controlling the tsetse, it has undesirable effects in other directions, particularly by encouraging soil erosion and by decreasing the fertility of the soil and water supplies. These assumptions have by no means

been proved. He produces convincing proof that bush-clearing is an anti-erosion measure in the semi-arid areas of East Africa, that grass ley may be equal or even superior to bush ley in the restoration of soil fertility following cultivation, and that there is some reason to expect that the effects of anti-tsetse and other bush-clearing may be beneficial to the water supplies in semi-arid country.

The carrying capacity of the land would be increased. As Hornby says, from his experience in Mpwapwa, "ten or more acres of even excellent land under bush may be required for one beast, whereas clearing and planting (with grass) the same land might yield pasture capable of carrying a beast to two acres the whole year round, where they could be watched and safeguarded from theft, vermin and disease. The development then of a system of pasturing cattle more and more on artificially created grassland is a measure that is necessary when tsetse are about, and is highly desirable even in the absence of fly".

Bush-clearing is invariably practised prior to cultivation. Patches or areas of land with good soil are selected for crops and it is not unusual to find the better soils in those places where the vegetation also forms the main habitats or permanent foci of the tsetse. These localities are practically always the first to be dealt with by discriminative clearing of bush. They may be small, numerous and scattered through the general bushland, or they may be fairly extensive—comprising a few acres, or about a quarter of a square mile or more. Other favourable habitats are found at the bases of hills (foothills) and are usually cultivable, or on the edges of seasonal swamps, as well as in the valleys or drainage lines, in the gallery forests along rivers or in the rich soils of thicket country.

Clearing for cultivation and production of crops—and maintaining production—will, of course, assist in liberating the land from tsetse and in holding the fly back effectively. Where infested bush occurs on uncultivable land (on the slopes or in ravines or tops of hills) inhabitants ought, as they are to-day, to be assisted by tsetse control teams.

One of the troublesome problems in connexion with bush-clearing, in the course of tsetse control, is that of regeneration and of the necessity of keeping it back so that re-infestation by tsetse does not take place. This again calls for the occupation of the land reclaimed and for its full utilization either for crops (where practicable) or for judicious and well-managed grazing, or for a balanced mixed farming. Co-ordination of bush-clearing for tsetse control and land use is indicated. There is also the question of timing tsetse control and the follow-up with settlement and development—assisted and supervised in native areas so as to demonstrate the advantages of good farming and of conserving the land and water supplies.

Where bush-clearing has to be undertaken in order to protect reclaimed or threatened areas, re-slashing or uprooting may have to be repeated at intervals. Intervals may be short if the land is good and the rainfall well distributed. They may be long if the soil is poor, or if the rainfall is low or not well distributed. A study of the plant succession and of the rate of regeneration in a variety of areas in East Africa would probably be of great advantage in arranging for the follow-up of tsetse control by planned settlement and development.

In many cases it is absolutely necessary to create barriers against reinfestation. These can often be reinforced by selective clearing of bush or, in the absence of grazing stock, by periodical controlled bush or grass fires.

Application of Insecticides

It has already been shown that tsetse can be controlled by the destruction of game in some instances, and by partial clearing of bush in others. While research in these directions must continue in order to discover more effective and cheaper methods against all species of tsetse, it is well to consider one of the most recent anti-tsetse measures which is still in its experimental (though advanced) stages in East Africa; namely, the application of the new insecticides D.D.T. and benzene hexachloride (B.H.C.), either in the form of spray or smoke from the air, or by ground apparatus.

The capital expenditure and overheads, as in the case of bush-clearing, are high in undertakings of aerial spraying. Like the bulldozers and chain-clearing too, the aerial sprayings can cover a relatively large area in a short time. The treated areas should be isolated by artificially made clearings or natural barriers in the first instance, so as to prevent reinfestation by tsetse from the rest of the fly country near by. In the South African projects against *G. pallidipes* in Zululand the permanent habitats and breeding sites of the tsetse were also destroyed by discriminative treatment of

the vegetation, and Government-owned aeroplanes and helicopters were used. The Colonial Insecticides Research Unit, now stationed at Arusha in Tanganyika, reports of considerable reductions of the tsetse populations in areas of bush which they have sprayed from the air in the islands infested with *G. palpalis* in Lake Victoria; in larger blocks of bush at Kikore in Tanganyika where *G. morsitans, G. swynnertoni* and *G. pallidipes* were present, and more recently against *G. morsitans* in one of the units of land which are being developed by the Overseas Food Corporation at Urambo in Tanganyika. In these experiments the reduction in the fly population reached up to 98.9 per cent, and even up to 100 per cent in one or two cases. This method should be of particular value in unhealthy and inaccessible places, such as the Maruzi district in Uganda is reported to be, where mosquitoes are said to be abundant by day and by night, and from where tsetses threaten the adjoining country which has recently been reclaimed.

The cost of a full series of sprayings from the air, as reported by the Colonial Insecticides Research Unit, is from £800 to £1,000 per square mile (or from Sh. 25 to Sh. 31/50 per acre). This does not take into account the cost of any preparatory bush-clearing for isolation from reinfestation, or the subsequent clearing (if necessary) of residual foci of infestation. If, howeveer, isolation can be effected by clearing only long stretches of the bushland which the tsetse must utilize (such as through gaps in hills or along certain types of woodland, on the edges or banks of rivers) in extending their range and invading new territory, the cost of isolation could be very much reduced. Such isolation is being tried out by the East African Tsetse and Trypanosomiasis Research and Reclamation Organization in collaboration with the Overseas Food Corporation and the Colonial Insecticides Research Unit at Urambo.

The spraying of riverine vegetation infested with *G. palpalis* has produced a very substantial reduction of fly on the Nyando River and its tributaries in the Nyanza Province of Kenya, according to reports by the Tsetse and Trypanosomiasis Survey and Control Unit of the Department of Veterinary Services. The spraying in this self-contained riverine basin was carried out by portable Seven Oak spray-pumps operated by mobile teams of Africans.

By insecticidal smoke (B.H.C.) generated from canisters distributed throughout bush infested with *G. swynnertoni* the fly population in Atta in Tanganyika was reduced by 98.1 per cent to the low level of 1.9 per cent.

Insecticides have already been used by the East African Tsetse and Trypanosomiasis Research and Reclamation Organization on cattle. When applied at frequent intervals and with sufficient density of cattle (about 60 or 80 per square mile), the fly infestation drops to very small numbers indeed in a period which can be predicted with a high degree of accuracy. Here, again, the area of land involved must be isolated and protected from reinfestation by immigrant flies.

The dipping or spraying of insecticides (D.D.T. and B.H.C.) have proved to be effective also against other flies which may be responsible for direct (in contrast to cyclical) transmission of animal trypanosomiasis.

Before concluding this section, it is advisable to mention at this stage that most of the anti-tsetse measures already referred to bring about a very appreciable diminution of the fly density and population. The elimination of the last few flies, so to speak, is often difficult, prolonged and costly. Even to find the last few flies is difficult, or to be certain that elimination has indeed been effected. In this connexion it has been noted on several occasions that the continual reports of animal trypanosomiasis, despite treatment with effective curative drugs, is the first indication of the presence (seasonally or constantly) of tsetse flies. For this reason fly surveys and well-planned regular patrols are essential; and the co-operation of the Veterinarian (and Medical Officer) is of considerable importance. It is equally important for the Tsetse Officers to work in close collaboration with the Agriculturalist, so that only bushland essential to crop-growing, for grazing and for tsetse control, is cleared. The remainder should perhaps be conserved for fuel and building until better supplies are available from plantations situated in suitable sites.

Other Anti-tsetse Measures

Brief mention may be made of other methods which have been employed in fly surveys, tsetse control measures and in determining the presence or in assessing the population of tsetse flies. They are hand-catching by human and animal "bait" or by the use of cloth screens; trapping; and the use of insecticide impregnated on adhesive cloth or paper.

Exclusion of bush and of grass fires has been used with some degree of success. When employed in conjunction with discriminative clearing of bush it has been more successful. Late burning, however, is said to be better especially in helping to prevent fly advances and in keeping the woodlands open, and thus discouraging the fly. Burning is also useful in keeping back thicket favourable at this stage to tsetse infestation. Burning is only useful when the grazing is light or non-existent. To quote Hornby again, "if it (the grazing) be light enough to permit occasional strong fires then browsing of transitional shrubs that always accompany grazing may help to stabilize the grassland stage; once, however, grazing is heavy enough to abolish fires then it always causes more severe setback to the grass than to the shrubs, and the succession tends to advance to a transitional shrub stage, and thence along the road towards development of a woody climax devoid of ground herbage".

Settlement and Land Use in Relation to Tsetse Control

It has already been suggested, explicitly or implicitly, how settlement can help in tsetse control (and vice versa) and consolidate the position in regard to reclaimed land, and at the same time use the land for production of food and profit. Much depends, however, on surveys designed to formulate plans of land utilization, the subsequent arrangement of settlements, and the help and supervision given in the development of the areas concerned. A demographic study may reveal the reasons for the emptiness of the vast areas of East Africa. The people who may once have lived in reasonably large communities—sufficient to maintain themselves and their land in good heart—may also have been decimated or wiped out by devastations of widespread epidemics such as that of smallpox in the '90's of the last century, or the havoc caused to stock and game by the spread of rinderpest at about the same time.

Lang (1927), MacLean (1929), Lewis (1942), Fairbairn (1943), Bax (1944), Ford and his colleagues (1948), Lester (1949), and others referred to events in the history of African tribes and to their effect on the distribution of the people and on the situation in respect of tsetse fly and trypanosomiasis. MacLean (1929), for example, has described how pacification resulted in the population dispersal in Tanganyika, and the subsequent appearance of *rhodesiense* sleeping sickness. He reconstituted the concentrations of the people as a prophylactic measure against the disease and as a defence against the tsetse—*G. morsitans*. Fairbairn (1943) describes these in his article on "The Agricultural Problems Posed by Sleeping Sickness Settlements". He writes of the selection of settlement areas with the assistance of the Chiefs and Elders, of moving people *en masse*, of the density required in the case of animals and persons, the acreage allotted to each family for clearing and cultivation, of the water supplies and the introduction of stock. Hornby also refers to the settlements and suggests a small number of rules to ensure their permanence and their extension. Fairbairn is of the opinion that "when a density of 50 to 80 (persons per square mile) is reached the country is generally sufficiently clear to be practically fly free". He adds that the native farm is a family affair. A family (or taxpayer) is equivalent to 3.3 persons in the Western Province of Tanganyika, where there were 28 settlements in 1943, that such a family cultivates each year about 4½ acres of land, and usually receives an allocation of about 16 acres of land. Morris (1949) records that *G. morsitans* in the Gold Coast does not occur in country with a population density above 15 per square mile. Nash (1948) is reported to require a minimum population of 70 per square mile for maintenance of his discriminative and protective clearings in Northern Nigeria as does McLetchie (1948), Medical Officer in charge of the Sleeping Sickness Service in Nigeria.

There must be additional information available on the optimum densities of people or of animals in various parts of East Africa, and on the acreage that can be utilized rotationally and productively for crops appropriate to particular localities. Such information, if available, would give an encouraging start to a plan of land utilization: it would also help to reduce the cost and to speed up tsetse control. The optimum density would naturally vary. Fertile and cultivable land uninhabited because of fly would hold many people who are now in overcrowded areas; land less suitable for crops could perhaps be improved to provide grazing for stock; exhausted lands, which have usually become fly-infested because of its abandonment and subsequent encroachment of bush, could possibly be reconditioned and restored to their former productivity by special measures; and the people could be returned to their own ancestral homes. Where the

capacity of the land to hold families is not known, it is suggested that investigations be set in train to determine the human density required to hold and to use the land profitably.

It is encouraging to note that information of this nature is being accumulated in the course of development schemes in East Africa as, for example, at Makueni (Kenya) and in Sukumaland in Tanganyika. In the former the fight against tsetse is followed by settlement. In the latter, a large area of about 3,000 square miles covered by the Sukumaland Development Scheme has been freed from fly and occupied during the last 15 years solely through pressure of population guided by a team of workers residing on the spot and aided by provision of water supplies. In Sukumaland, with fly in the bush ahead, animal trypanosomiasis presents its inevitable problem of when and where to introduce stock. The same applies to places like Makueni, Lambwe Valley, Tabora, Urambo, and many other areas where tsetse-infested land is required or being reclaimed for settlement. A good deal of research connected with this aspect of the problem is necessary. The programme of research into animal trypanosomiasis (as in human sleeping sickness) which the East African Tsetse and Trypanosomiasis Research and Reclamation Organization has prepared and recently put into effect has been so arranged as to cover this particular problem.

Here, however, one may interpose with a few points often raised in connexion with the settlement of tsetse-infested land: for how long can a piece of land be occupied and cultivated without having to introduce cattle; how many beasts can the allotted acreage per family carry; and when may cattle be taken on to the land and secured from infection by trypanosomiasis?

The answer to the first of these points can be obtained from the study of the custom and practice of many sections of the African tribes in Kenya, Uganda and Tanganyika. With regard to other points, Fairbairn, referring to the sleeping sickness settlements in Tanganyika (which were at least 15 square miles and large enough for 1,000 taxpayers), reports that there was sufficient room in the centre of the settlement to allow of cattle being introduced (in *morsitans* country) and kept free from trypanosomiasis. In practice, cattle were introduced six years after the settlement had started if the boundaries of the settlement had been clear-felled half a mile in depth. Small stock were introduced from the second year onwards. Fairbairn does not, apparently, commit himself on the question of how many beasts should be kept by each family, or on the number of acres that should be allotted to each beast. Hornby, on the other hand, writes only of the carrying capacity of reclaimed land in the vicinity of Mpwapwa (Tanganyika). He states that it was found possible to keep a beast on two acres the whole year round where previously it required ten acres for one beast. Such an experience is not unknown in other parts of East Africa as, for instance, the writer believes, in Makueni, Kenya. Further data in this respect would be of value for planners and managers of schemes to make more land available for mixed farming and ranching.

One is not unmindful of the recommendations of the Committee on Trypanosomiasis and Tsetse Fly to the British African Land Utilization Conference held at Jos, Nigeria, in 1949. Dealing with agricultural projects and resettlement of reclaimed tsetse country, it is recommended that " . . . while clearing is taking place, and so before achieving eradication of the fly, the human population must and can be given adequate protection by chemotherapy against acquiring sleeping sickness. Pending consolidation of the position by large-scale cultivation it would be, in our opinion, most unwise to introduce cattle but there would be no objection, if it were considered desirable, to bringing in the small livestock, i.e., sheep and goats, but not pigs. . . . The introduction by the settlers of cattle is not recommended at the outset. . ." The Committee also recommended "when it is eventually thought possible to bring in the larger livestock", that indicator herds should first be used to test out whether or not introduction of cattle can be undertaken with safety.

This aspect of animal trypanosomiasis presents a large variety of different questions and problems. It calls for a considerable range of investigations—basic and *ad hoc* research. It offers a fruitful field for the veterinarians, the ecologists, the protozoologists and the chemists. It concerns the biologist who studies the flies, their environment and how they become infected with the trypanosomes they carry. The effect of the species of fly, its physiology, and the conditions under which it lives on the parasite and its development in the fly need attention. The infectivity of the tsetse with the different trypanosomes, and transmissibility, could profitably be studied. The fate of the

trypanosomes—species and strains—in domestic animals and game—is not well known; nor is much known of the tolerance and sensitivity of stock—under all conditions of climate and health—to infection. The part played in the transmission of trypanosomiasis in some parts of East Africa by biting flies other than tsetse is being investigated by the East African Tsetse and Trypanosomiasis Research and Reclamation Organization, and the subject of immunity in cattle is being continued. Amongst the more immediate problems is that of chemotherapy and chemoprophylaxis against animal trypanosomiasis and, of course, the related problem of "drug-fastness" which inevitably arises and creates controversy and frequent disappointment.

To what extent and when can drugs be administered safely and with advantage? To what degree can they be used—not so much to enable cattle to be kept indefinitely in fly-infested bush, but to help in the full settlement of a reclaimed area at an early date and, perhaps, to hasten the eradication of the last few flies which is so often prolonged and expensive?

Recent reports from the Lambwe Valley (Kenya) show how the number of cases of trypanosomiasis in the herds of cattle in the neighbourhood have dropped substantially since the animals were periodically treated, by the territorial Veterinary Officer, as the fly population in a part of the valley was being reduced by the East African Tsetse and Trypanosomiasis Research and Reclamation Organization's experiments in discriminative clearing against the tsetse, *G. pallidipes*. The results, so far, indicate the advantages following drug treatment in these circumstances. They also suggest that while permanent control means vector control, the latter can be achieved more readily and economically by an attack on both the tsetse and trypanosomiasis; thus, too, using the cattle to assist the final stages of fly eradication; and giving encouragement to the settlers to contribute to the full and proper use of the land and development.

Conclusions

Much has been done in the East African territories to prevent the advance of tsetses on to land under occupation, and to reduce losses from trypanosomiasis. Infested areas have been reclaimed either in the course of protecting occupied land and in order to provide additional land for increasing populations of man and stock, or to relieve congested areas in the native reserves. The territorial establishments concerned with the control of the vector and the disease have unquestionably made considerable progress. Research has contributed a substantial share to the success achieved. Much more needs to be done in the way of research. In the meantime, however, the present methods available against most species of tsetses make it possible in practice to release more land, if required, for the relief of exhausted land, expansion and agricultural development.

Successful tsetse control involves a number of other issues. In protective schemes the fly front must be held by "barriers" in the form of well-maintained strips of treeless country, by fences or constant patrols to prevent wholesale reinvasion by game or regular movement of stock from infested to reclaimed land, or by clearings or judicious settlement either along the whole front or at strategic sections where the conditions are suitable for fly concentrations and infiltration.

In reclamation schemes, measures against reinfestation are also necessary and may comprise one or more of those mentioned above or by discriminative clearing of bush, based on detailed fly and vegetation surveys for which research workers have produced a useful technique applicable to most fly-infested areas. In many instances, study of the vegetation, fly distribution and population reveal stretches of country which are almost natural barriers which can fairly readily be made more effective.

Utilization and development of the reclaimed land are, however, the best form of consolidation, and the most economic. They constitute a powerful factor in keeping the tsetse at bay and in maintaining conditions unfavourable to the fly.

The planning phase, from the tsetse aspect, is preceded by detailed surveys. Similar surveys are required for subsequent use of the reclaimed land. Watering places need to be determined or provided. Information is required on the climate and all that it means; on the amount and distribution of rainfall; on the nature of the soil, on localities suitable for cultivation or grazing; on the optimum density of population and the distribution of families and villages. The stock-carrying capacity of the land needs to be ascertained, and the prospects of pasture improvement and upkeep of crop production.

Information on some of these is no doubt available for a number of districts in the territories. More could readily be obtained by temporary smallholdings distributed throughout the reserves—and in localities reclaimed from tsetses—in charge of Africans and under the general management and guidance of specially trained officers.

The data collected from such surveys and studies could be collated in respect of every aspect of land reclamation and land use. A comprehensive and practical plan of development could be devised and put into effect more economically. Greater security from re-infestation by tsetses would be ensured, and the control of trypanosomiasis would be simplified.

It implies far more than the mere co-ordination of the work between the organizations directly concerned with the control of tsetses and trypanosomiasis. It calls for the closest liaison and co-operation with other bodies concerned with the land and its development—the research worker and the applied scientist, the executive and the administrative officer. Each project must be put into practice with that spirit of team work and management on the spot which will ensure continual progress and success.

REFERENCES

Potts, W. H., and Jackson, C. H. N. (1952). The Shinyanga Game Destruction Experiment—Bull. Ent. Research, Vol. 43, Part 2, July, 1952, pp. 365–374.

Du Frayer, A. G. H. (1951). Annual Report of the Tsetse Survey Reclamation Department consolidated up to and including 1949, p. 7. Printed by Govt. Printer, Dar es Salaam, Tanganyika.

Hornby, H. E. (1941). Pasture Management in Relation to Tsetse Reclamation—*The East African Agricultural Journal*, July, 1941, pp. 51–55.

Staples, R. R. (1941). Anti-tsetse, Clearing and Land Use—*The East African Agricultural Journal*, July, 1941, pp. 48–50.

Lang, H. (1929). The Tsetse and Nagana—Pamphlet issued by The Wild Life Protection Society of South Africa.

MacLean G. (1929). The Relationship Between Economic Development and Rhodesian Sleeping Sickness in Tanganyika Territory. Ann. Trop. Med. and Parasit. 23, No. 1, pp. 37–46.

Lewis, E. A. (1942). Tsetse Flies and Development in Kenya Colony—*The East African Agricultural Journal*, Vol. 7, No. 4, pp. 183–189, Vol. 8, Nos. 1–2, pp. 9–14, 74–79.

Fairbairn, H. (1943). The Agricultural Problems Posed by Sleeping Sickness Settlements—*The East African Agricultural Journal*, Vol. IX, pp. 1–6.

Bax, S. N. (1944). A Practical Policy for Tsetse Reclamation and Field Experiment. Reprinted from *The East African Agricultural Journal*, Vol. IX, 1943.

Ford, J., Whiteside, E. F., and Culwick, A. T. (1948). The Trypanosomiasis Problem. *The East African Agricultural Journal*, April, 1948, pp. 187–194.

Lester, H. M. O. (1949). The Relationship between Trypanosomiasis and Development in Tropical African Rural Communities—communication (No. D (m) 12), to the African Regional Scientific Conference, Johannesburg, 1949.

Morris, K. R. S. (1949). Planning the Control of Sleeping Sickness—Trans. Roy. Soc. Trop. Med. and Hyg., Vol. 43, No. 2, pp. 166–167.

Nash, T. A. M. (1948). The Anchau Rural Development and Settlement Scheme, p. 7—Colonial Office, London, H.M.S.O.

McLatchie, J. L. (1948). The Control of Sleeping Sickness in Nigeria—Trans. Roy. Soc. Trop. Mtd. and Hyg. ,Vol. 41, No. 4, pp. 445–471.

A REVIEW OF PRESENT METHODS OF IMMUNIZATION AGAINST RINDERPEST IN KENYA

By S. E. Piercy, Department of Veterinary Services, Kenya

(*Received for publication on 7th May, 1953*)

The past decade has seen rapid progress in our knowledge of the most effective means of protecting stock against rinderpest, a disease which, although now well under control in East Africa, must still be regarded as potentially a major epizootic. It is no exaggeration to say that the control of rinderpest has been almost revolutionized.

Prior to the second world war, reliance was placed on four methods of immunization or control. The first of these, which at that time had already been largely abandoned, was the "vaccine-virus" method. This consisted of an initial inoculation of harmless inactivated spleen vaccine causing a partial immunity, reinforced after a suitable interval with a dose of virulent bovine virus, effectively conferring a solid and lasting resistance. The second procedure, known as the "serum-simultaneous" method, consisted of a double inoculation, virulent bovine virus being injected on one side of the animal and a suitably graded dose of hyper-immune serum on the other.

Both these methods had serious disadvantages in that they necessitated the use of virulent virus. In consequence, it was necessary to place farms on which cattle were being immunized into quarantine to prevent the disease from spreading to susceptible cattle or game in the immediate neighbourhood. In addition, there was the danger that animals receiving inactivated vaccine followed by virulent virus might not be adequately immunized because the former might "block out" the latter or, conversely, that the virulent virus might break down the low-grade resistance engendered by the inactivated vaccine and cause violent reactions or death. Similarly, when using the "serum-simultaneous" method, it was only by virtue of considerable experience that veterinary officers were able to estimate the correct amount of serum to give so that the virulent virus was neither "blocked out" nor permitted to cause undesirable reactions or mortalities. A further disadvantage was the danger of accidentally transmitting protozoal diseases such as redwater when using virulent virus in the form of freshly drawn bovine blood.

It will be evident that the application of these methods of immunization demanded great care, skill and nicety of judgment on the part of the officers concerned and to a later generation, accustomed to the use of safe attenuated vaccines, it appears surprising that cattle were so successfully immunized without more grave accidents than did actually occur.

The third product, loosely referred to as "spleen" vaccine, consisted of a preparation of spleen pulp, taken from animals in the febrile stage of artificially induced rinderpest, to which formalin was added to kill the virus. This preparation, properly termed "inactivated spleen vaccine", was primarily designed for very susceptible, high-grade or pure-bred stock and dairy cows in which reactions following procedures involving the use of virulent virus would be dangerous, or undesirable in the case of cows in milk. Since the vaccine contained only dead organisms, it was quite safe to use in any class of stock, but the dose necessary was large, the resultant immunity was slow to develop, and a course of three inoculations at suitable intervals was found to be necessary to confer an effective resistance for the first year, after which one annual inoculation maintained the immunity at an adequately high level.

The use of inactivated spleen vaccine had one great advantage in that, despite the drawbacks just enumerated, the European stockowner himself was permitted to carry out the inoculations. He was thus able to arrange the immunization of the animals at his own convenience and without being placed in quarantine, whilst the district veterinary officer and his staff were enabled to devote the time saved to other responsibilities.

Finally the use of hyper-immune serum was extensively practised until the advent of live attenuated vaccines. The immunity conferred by this means was immediate but of short duration, a matter of two to three weeks only. The main value of serum was to afford rapid protection to cattle in imminent danger of being exposed to the disease until the outbreak could be controlled by other measures,

and to prevent a spread of infection by imposing a ring of immune cattle around the focus of infection.

Of the methods which have so far been described, only one has survived to the present day, namely, the use of inactivated spleen vaccine for highly susceptible cattle. This vaccine has remained popular because, until two years ago, there was no other method of immunizing high-grade and pure-bred cattle or lactating cows without the risk of causing undesirable reactions. With the advent of lapinized vaccine, to be described later, which causes little or no reaction in cattle in East Africa, it seemed at one time as though inactivated spleen vaccine might also be discarded, but recent experimental work, which has resulted in a much-improved product, suggests that it may again regain favour. The fact that it may be safely administered by the European stockowner himself will always influence the minds of those whose responsibility it is to decide which particular method of immunization should be recommended.

During the past few years attention has been paid to a method of increasing the immunizing value of inactivated vaccines by the addition of certain chemicals and oils which have the effect of localizing the inoculum in a "pocket" under the skin of the inoculated animal and thereafter permitting its slow release over a prolonged period. These substances are commonly known as "adjuvants" and their effect is to provoke a more solid and durable immunity and also to permit a substantial reduction in dose. An example may be found in the present blackquarter vaccine issued from Kabete in which the immunizing bacteria are precipitated and rendered comparatively indissoluble with aluminium hydroxide.

Using the same chemical, investigations have been carried out with rinderpest inactivated spleen vaccine with encouraging results. More recently, even better results have followed the use of other types of "adjuvants" and a number of large-scale field trials are at present in progress. If the successful laboratory trials are substantiated, it may be possible to issue a much-improved and cheaper product causing a stronger and more durable immunity with greatly reduced dosage.

Attenuated Vaccines

Since the discovery, many years ago now, that certain viruses when made to grow in unusual hosts may undergo fundamental changes so that they are no longer capable of reproducing their original pathogenic effects when returned to their rightful host, the whole concept of immunization against virus diseases has been revolutionized.

In the animal world an early example of the way in which this phenomenon can be put to practical use is afforded by the work of Alexander, now Director of Veterinary Services in the Union of South Africa, who was able to adapt strains of African horse-sickness virus to growth in the brains of white mice. After about 100 serial mouse-to-mouse transfers, it was found that mouse brains infected with virus could be suitably prepared and inoculated into horses with safety, with no greater adverse effect than a mild febrile reaction. Immunity developed slowly but was solid for a period of about a year.

The process by which this modification occurs is not clearly understood. Some workers consider that a structural alteration in the composition of the virus body occurs which renders it less pathogenic for the original host. Others believe that any given strain of virus is composed of a mixed population of organisms, some being more pathogenic than others in much the same way as within a race of human beings a great variety of physical characteristics may be present. By obliging this mixed population of virus organisms to propagate in unnatural hosts, it is thought that those which are most pathogenic for the original host may sometimes be overgrown by less virulent types of organism which cause only a mild reaction although still capable of stimulating an adequate immunity. Finding a suitable foreign host, usually a small animal such as the mouse, rabbit or guinea pig, is the virologist's task when investigating the possibility of modifying a virus pathogenic to humans, farm animals or domestic pets. In the initial stages the success of this procedure is very often a matter of luck since it is impossible to know in the first place which small animal will prove susceptible. In some instances a very wide range of animals, birds and rodents has been screened before success has been achieved and in others it has been found impossible to induce the virus concerned to grow in any tissue other than its own host.

In recent years a considerable advance has been made in this method of modifying harmful viruses by persuading them to grow in fertile hens' eggs. Embryonated eggs provide an ideal medium for virus growth in that they

are constant in physical and chemical properties, free from bacterial contamination, easy to handle and comparatively cheap. Some viruses show marked preference for growth in different portions of the egg. For example, the pox group of organisms grows most readily on the vascular membrane lining the inside of the shell; the pneumonic viruses prefer the fluids surrounding the embryo; others adapt themselves more readily to growth in the developing embryo itself, whilst the rickettsiæ, which are not strictly speaking members of the virus group of organisms, will only thrive in the yolk sac. By a series of delicate procedures the skilled technician can open the living egg, deposit the virus in the particular site of choice, close it up again and return it to the incubator to continue its development. After a suitable period of time, usually three to five days, the eggs are removed, opened up and those portions in which the virus has been multiplying are collected and rendered into a fine emulsion suitable for further use. In the majority of cases, embryonated eggs are killed by the viruses they are made to harbour, but a few viruses, for example, those of rabies and distemper, can grow in developing eggs without causing their death.

In no disease, whether of human or animal origin, has this principle of attenuation of viruses in unnatural hosts been better demonstrated than in rinderpest. Kabete attenuated goat virus vaccine ("K.A.G.") has achieved universal fame, and rabbit-adapted virus (lapinized vaccine) is being increasingly used in territories where cattle of unusual susceptibility must be protected. In addition, the potentialities of an egg-adapted vaccine have been studied in China, the United States of America, and in East Africa with considerable success.

The possibility of producing a suitably attenuated live rinderpest vaccine by adapting the virus to the goat was first investigated in India many years ago and credit must be given to veterinarians in that country for first demonstrating the practicability of this method. A few years before the second world war this process was further pursued at Kabete using local strains of virus. As the virus was passed through successive generations of goats it was found that it became less pathogenic for cattle in inverse ratio to the number of completed goat passages. Finally, after several hundred serial transfers in goats, it was found that the virus present in goat spleen could be safely inoculated into native cattle without causing anything more than a moderate reaction followed by solid and lasting immunity which, for all practical purposes, is considered to be permanent. In the early days, due to slight imperfections of the technique of manufacture and preparation in the field, a mortality of 1–2 per cent was expected. When the African realized, however, that a single inoculation would create permanent immunity in his cattle, he was persuaded to accept a small death-rate. Very considerable advances in the techniques of preparation have been made since then, however, and with the exception of certain highly susceptible breeds such as the Ankole, the present "K.A.G." vaccine is not expected to cause any mortality in indigenous types of cattle. Severe reactions do sometimes occur depending, to some extent, on the condition of the cattle and the state of the grazing at the time of inoculation, but providing due care is taken to inoculate cattle under optimum conditions no deaths whatever should occur.

Since the advent of "K.A.G." vaccine, over fifty million cattle have been successfully immunized, not only in East Africa, but also in other territories such as the Sudan. The number of doses issued from Kabete increases year by year; for example, in 1951 this was over 6,000,000, in 1952 7,000,000, and it is anticipated that in 1953 this figure will again be exceeded.

"K.A.G." vaccine is designed and is essentially most suitable for indigenous cattle which have some inherent resistance to rinderpest. It has been and still is used to some extent in low-grade cattle although fairly severe reactions may be expected. In some areas, farmers have attempted to obviate severe reactions by the simultaneous inoculation of small doses of serum. This has proved to be a most undesirable procedure for, when outbreaks of rinderpest occurred some years ago in these areas, it became obvious that a percentage of cattle which had received serum in addition to virus had not been effectively immunized and many deaths occurred. "K.A.G." plus serum vaccination was largely practised in European ranching areas and since in those days the only alternative was to use inactivated spleen vaccine, a cumbersome method of immunization, it is understandable that this method was popular with many ranch farmers. They were faced with the problem of immunizing cattle whose natural susceptibility to rinderpest was such that "K.A.G."

virus might prove too strong, yet their value and the manner in which they were kept precluded the use of inactivated spleen vaccine, the only other method then available. Had not another live vaccine of a milder type been discovered (lapinized vaccine) it is likely that this would still constitute a serious problem.

The possibility of adapting the rinderpest virus to rabbits in the search for an alternative to goat-adapted vaccine has been pursued for many years by scientists in Japan and China. The fact that rinderpest virus could be made to grow in rabbits had been noted many years ago by British veterinarians in India but, unfortunately, this research was not pursued. Many types of cattle in the Far East are so highly susceptible to rinderpest that even attenuated goat virus vaccines are too strong and cause severe mortality. It is understandable, therefore, that Japanese and Chinese scientists should have pursued with vigour the potentialities of an even milder type of vaccine produced from the rabbit. Eventually, they were successful and in 1947 rabbit-adapted (lapinized) vaccine was used on a field scale.

The first field inoculations were made with "wet" material, that is a mixture of spleen, gland and blood taken from rabbits reacting to the disease, diluted in saline and inoculated into cattle within a few hours of preparation. This procedure was necessary because at that time adequate facilities for drying the vaccine were not available. It required the provision of teams of inoculators and vaccine preparators who moved about from district to district, manufacturing the necessary amounts of vaccine on the spot from locally procured rabbits. This in turn necessitated efficient preliminary planning and the complete co-operation of Government administrative officials.

At about this time, strains of lapinized virus were sent to Kabete for further investigation. The findings of the Far Eastern workers were soon confirmed and a new production block was built with adequate facilities and machinery to render the "wet" material into a dried product in which form, under efficient conditions of cold storage, the vaccine was found to keep for long periods.

It was immediately realized that this type of vaccine was the answer to the problem of the immunization of highly susceptible stock. Although no clinical reactions following inoculation could be observed, even in pure-bred stock, such animals were found to be solidly immune when challenged with virulent virus. The fact that no observable reaction occurs is both an advantage and a disadvantage. Thus, with "K.A.G." vaccine, following the use of which a marked temperature reaction and usually some slight sickness occurs, it can easily be assessed whether or not a herd has been satisfactorily immunized. With lapinized vaccine, however, immunity must be presumed, although, providing the animals concerned are fully susceptible at the time of inoculation, there is no reason to doubt whether or not they have been satisfactorily protected. The absence of reactions with lapinized virus, however, is of immense advantage when highly susceptible cattle are to be immunized. Thus, pure-bred cattle and even imported bulls from Europe or South Africa can be inoculated with this vaccine with impunity. In other ways, too, lapinized vaccine has great advantages. For instance, should it be desirable to immunize cattle in a poor state of health, or cattle which are to be trekked through a fly-belt, lapinized virus can be used without fear of ill effects.

The duration of immunity engendered by lapinized vaccine is still unknown, since this product has only been in regular use for a few years. It was originally thought, since the virus is of a very mild nature, that the immunity it produced would be of about one year's duration only. However, as a result of a series of investigations commenced some two years ago, it now appears that when used in cattle of high susceptibility, the immunity engendered by lapinized vaccine may be of two years' duration or more. The length of immunity in native cattle is unknown but since they are comparatively resistant to rinderpest and, therefore, respond less actively to the inoculation of lapinized virus, it is likely that it will be shorter.

A remarkable virtue possessed by both "K.A.G." and lapinized vaccines is known as the "interference phenomenon". By this is meant the ability to cut short an outbreak of the disease by "blocking out" the natural virus. Thus, when cattle start dying of rinderpest, if either "K.A.G." or lapinized vaccine is inoculated immediately, fresh cases cease to appear after about three days in the case of "K.A.G." and five days in the case of lapinized virus. The precise mechanism by which this "interference" is brought about is not entirely understood, but it is thought that the attenuated virus, when inoculated into the animal's

system, occupies or attaches itself to certain cells of the body effectively preventing their invasion by virulent virus. Before the advent of attenuated vaccine, the only means of immediate control was to administer large doses of hyper-immune serum. This was costly and difficult to produce. Furthermore, its effect was only of some three weeks' duration. By using attenuated vaccine, outbreaks can be controlled promptly and very much more cheaply. Furthermore, such animals are immunized permanently, in the case of "K.A.G.", or for a period of one to two years if lapinized vaccine is used.

Another interesting and most important feature of attenuated vaccines is that their use is not followed by the spread of the disease from reacting animals to others in contact. When this fact is compared with the danger of spreading rinderpest when using the old serum-simultaneous method, which involved the use of live virulent virus, necessitating the imposition of quarantines on farms receiving this type of vaccination, the outstanding advantages of attenuated vaccines become even more apparent.

Not least among the virtues of dried attenuated rinderpest vaccines is their remarkable keeping properties. Thus, "K.A.G." vaccine maintained at temperatures well below zero has remained fully potent and viable after two years' storage. Similarly, lapinized vaccine has been maintained in a similar way for periods of over 15 months. Even at ordinary refrigerator temperatures they remain viable for periods of up to three months. Consequently, they can be prepared and stored in bulk against future demands and can be distributed over very wide distances without deterioration. Both "K.A.G." and lapinized vaccines have been sent from Kabete to territories as far afield as the west coast of Africa, the Middle East countries and India. Vaccines destined for territories such as these are normally despatched on ice, but on two occasions at least lapinized virus has survived without ice for periods of at least 28 days although subjected to unknown variations of temperature *en route*. Finally, since attenuated rinderpest vaccines are issued as dried material, they occupy a minimum of space, up to 500 doses in a single ampoule weighing less than a quarter of an ounce.

An outline of the methods used in the preparation of attenuated rinderpest vaccines may be of some interest to illustrate the precautions and safety measures adopted to ensure that the final product is viable, potent and safe.

With both "K.A.G." and lapinized vaccines "banks" of stock viruses of proven efficacy and safety are maintained under suitable conditions of storage. Successive batches of vaccine are initiated by inoculating the animals concerned (goat or rabbit) with virus drawn from these "banks". The object of this procedure is to ensure that vaccine is prepared from a generation of virus of proven satisfaction and to avoid attenuating stock viruses beyond a desirable level of virulence. There is always a risk of the latter if vaccine virus is maintained simply by setting aside sufficient material from each successive batch to initiate the next. By "banking" large quantities of a selected generation, the stock strains need not be further passaged through goats or rabbits for a number of years.

In both goats and rabbits the inoculation of vaccine virus is soon followed by characteristic temperature elevations. At the peak of fever, the animals are destroyed for the collection of certain selected tissues which experiments have shown to yield the highest amounts of uncontaminated virus. These tissues, spleen from the goat, and blood, spleen and gland from the rabbit, are then emulsified in special mincing and crushing machines. Bacteriocidal agents are added to overcome any accidental airborne contamination and the emulsions placed in special bottles which are attached to a bulk vacuum drying machine. The evacuated moisture is either absorbed by a chemical desiccant or made to freeze on the outer surface of a vessel containing a mixture of "dry ice" and alcohol at a temperature of about $-70°$ C.

After several hours on the bulk drier, the vaccine material is removed from the bottles and dispensed into small glass ampoules in accurately weighed quantities. These are attached to a second high-vacuum drying machine which further reduces the moisture content and makes provision for the ampoules to be sealed off, whilst still under vacuum, with a small oxy-acetylene flame. After labelling, the ampoules are stored in a deep-freeze machine at about $-25°$ C.

Representative samples of each batch of vaccine are tested for safety and immunizing ability as follows: The dried material of an ampoule, selected at random, is dissolved in saline and from this a series of increasing

dilutions is made, each one being inoculated into susceptible cattle. The strongest dilution is given to reveal any dangerous pathogen, such as the anthrax bacillus, that might have been present in the goat or rabbit from which the material was originally obtained. With this animal is placed another susceptible steer whose function is to reveal by clinical reaction any virulent virus that might accidentally have gained access to the vaccine and which might spread from inoculated animals to neighbouring cattle should such vaccine be mistakenly issued to the field.

The test animals' temperatures are observed over a period of about ten days and the highest dilution of the vaccine still able to cause reactions noted. Since lapinized virus does not normally cause temperature reactions, an assessment of the optimum vaccine dilution cannot be made at this stage. The test animals are then removed from the attenuated rinderpest vaccine production block and "challenged" elsewhere with virulent rinderpest virus. Again the highest dilution of vaccine which has conferred solid immunity is noted. The uninoculated control which was placed in contact with the animal receiving the strong dilution should, of course, prove to be susceptible by reacting to this "challenge". In addition to these precautions, further biological tests for safety are carried out by the inoculation of reconstituted vaccine into mice and guinea pigs.

From all these observations, the dilution factor of any particular batch, that is, how many doses a gramme of dried vaccine will yield, can finally be assessed.

Having discussed the two major rinderpest vaccines issued by the department, it now remains to consider the remaining product, namely, inactivated spleen vaccine. It might appear that "K.A.G." and lapinized vaccines are adequate for all requirements, since the one is entirely satisfactory for nearly all types of indigenous native cattle and the other for high-grade and pure-bred animals. It is, however, highly desirable that they should only be administered by members of the veterinary staff. In spite of their remarkable keeping qualities in the dried state they are extremely fragile when reconstituted with saline or water prior to inoculation and it is essential that they then be handled with very great care. A major virtue of inactivated spleen vaccine, being a killed product, is that it can be safely used by the European stockowner himself. The present inactivated spleen vaccine is a bulky product and the method of administration is comparatively cumbersome in that cattle immunized for the first time must receive three doses at short intervals, their resistance being reinforced annually with a single inoculation. Attention has, therefore, been directed to a modification of this product which promises to effect an increase in potency and a reduction in dose. Very considerable progress has been made, and it now appears likely that an improved inactivated spleen vaccine will shortly be available which will immunize cattle with a single dose. It is also anticipated that the duration of immunity, previously considered to be not more than 12 months, will be increased.

Apart from the desirability of issuing a vaccine which can be used by the farmer himself, there is another aspect of immunization to be considered which makes it preferable for this type of vaccine to be available as required. Animals which have previously received inactivated spleen vaccine cannot easily be reimmunized with attenuated vaccines. Investigations have shown that some ten months after immunization with inactivated spleen vaccine sufficient residual immunity remains to "block out" the effects of attenuated vaccines. On the other hand, during this period, such animals may not be sufficiently resistant to withstand the effects of exposure to a natural outbreak of the disease. It is known that some 15 months after inoculation with inactivated spleen vaccine, animals become sufficiently susceptible to react to attenuated vaccines so that their immunity can be satisfactorily reinforced. There is then, a short period between ten and fifteen months after the use of inactivated spleen vaccine during which an animal may be susceptible to virulent natural virus although refractory to the inoculation of attenuated viruses. With such animals, therefore, there is the danger of failing to immunize with attenuated viruses by inoculating them too soon after a previous inoculation of inactivated spleen vaccine. The unsatisfactory alternative is to leave them inadequately protected, during which time they might be exposed to natural infection, until they become sufficiently susceptible to react to attenuated vaccines. It is for such animals that an improved inactivated spleen vaccine has a definite application.

The reinforcement of low-grade residual immunity remains the one outstanding problem in the control of rinderpest. In addition to the

difficulties already enumerated, there is also the question of calfhood immunity to be considered. During the past decade a state of permanent immunity amongst native-owned cattle has been created in areas where annual inoculation campaigns have been carried out in at least 90 per cent of the adult stock of Kenya and Tanganyika. In consequence, the vast majority of calves are born from immune dams. An adequate resistance which protects the calf during early life is acquired through the colostrum and during this time immunization with attenuated vaccines cannot be effected. After an unknown period of months, the colostral immunity declines and there is then a period when calves are in the same position as adults whose immunity has waned following the use of inactivated spleen vaccine. They become susceptible to natural infection but are still refractory to attenuated vaccine virus.

This state of affairs is particularly evident in certain areas of Tanganyika where wild game constitutes a permanent reservoir of infection. In that territory "smouldering" rinderpest in calves between six and twelve months of age is a constant source of concern. The solution to this problem depends very largely on the elaboration of a laboratory test which will reveal the state of an animal's immunity at any given time. This can be done in many other diseases by testing the subject's serum for the presence of specific antibodies which, in turn, can be related to the animal's immune state. Unfortunately, in spite of extensive research, no such test has yet been devised for rinderpest. Research continues, however, and some progress has already been made. Once it is possible for the laboratory worker to estimate the state of an animal's immunity, the correct time for the successful application of attenuated vaccines can then be assessed.

BACK NUMBERS

The Editor would be glad to purchase the following back numbers of this *Journal*:—

Vol. I, Nos. 1, 2, 5 and 6; Vol. II, Nos. 1, 4, 5 and 6; Vol. III, Nos. 1, 2, 3, 4, and 5; Vol. IV, No. 6; Vol. V, Nos. 1, 3 and 5; Vol. VIII, No. 4; Vol. IX, Nos. 1, 2 and 3; Vol. XI, No. 2.

P.O. Box 21, Kikuyu, Kenya

NOTES ON OEMIDA GAHANI DISTANT (CERAMBYCIDAE)

By J. C. M. Gardner*, E.A. Agriculture and Forestry Research Organization

and

J. O. Evans, Kenya Forest Department

(With a note by H. H. C. Pudden, Silviculturist, Kenya Forest Department)

(*Received for publication on 15th March,* 1953)

Oemida gahani is a beetle which, in its larval stage, can cause serious damage not only to seasoned wood but also to certain species of trees in plantations. The investigations on which this account is based have been of comparatively short duration and have been hampered by shortage of staff, but it seems advisable now to summarize what information we have so that future workers, including those forest officers in charge of affected areas, may appreciate the situation. At the same time gaps will become apparent in our knowledge of this project which should be regarded as a long-term one. Although damage has so far been recorded only from Kenya it may well be expected in Tanganyika and Uganda.

History

The beetle was first described, as *Paroeme ghani*, by Distant (1892) from a specimen taken in the Transvaal. Later Gahan (in Distant, 1904, p. 106) created the new genus *Oemida* for the species; in the same place Distant remarks "Mr. Gahan has here founded a new genus for the reception of this species which I found a very scarce one. I procured a single specimen in 1891 and during a subsequent three years' collecting never met with another till I found it one day literally swarming in an old lumber room. This was my last acquaintance with the species. It varies in length from 10–17 mm.". Localities given in this reference are Transvaal; Pretoria, Zoutpanberg, Shilouvane.

In this connexion the Chief of the Division of Entomology, South Africa, in answer to a query made in 1950, stated that there was no additional information. The apparently isolated case of the beetle "literally swarming" in South Africa remains something of a mystery.

The next reference in literature seems to be a brief record by Wilkinson (1939 (1937), p. 93) of *Oemida gahani* damaging seasoned *Podocarpus gracilior* timber in Kenya in 1937; the next reference is by the same author (1939 (1938), p. 79) and is more ominous: "The Cerambycid, *Oemida gahani*, Dist. found in *Podocarpus gracilior* is becoming a serious menace to the timber structure of many of the earlier buildings of Nairobi. The effects of this borer have not been noticed until quite recently and in some cases joists and roof supports have been so seriously damaged that their safety limit has been reached. In the case of one large hotel the results of the work of this beetle have necessitated structural alterations costing several thousand pounds sterling. The insect appears to confine its attacks to the one timber *Podocarpus gracilior*. The exit holes made by the adult are small, varying in size from 2 mm. by 1 mm. to 5 mm. by 3 mm. It may be noted that later records show that attack is not limited to *Podocarpus*.

From the plantation aspect *Oemida* damage seems first to have been noticed in cypress timber at sawmills in or about 1945 (Report of Kenya Forest Department, 1945–47, p. 13); presumably this timber was derived from thinnings from the first commercial plantations of these exotic species made in 1926; incidentally, there is some confusion in this reference between *Oemida* and another common but relatively unimportant Cerambycid, *Chlorophorus carinatus*. Wimbush (1945, p. 6) says that cypress plantations had not been damaged by insects up to that date; this really means that damage had not been noticed for, as will be shown later, attack on living trees is not evident.

---

* The senior author was appointed as Forest Entomologist, Kenya, at the end of December, 1949, and transferred to E.A.A.F.R.O. on 1st October, 1951. He has been assisted by Michael Kangeri, an African youth fresh from school from April, 1950 on. In April, 1952, the junior author was detailed by the Kenya Forest Department to assist in the work and is in process of establishing a field station at Londiani; he has been chiefly engaged in field experiments involving felling and analysis of trees for statistical purposes. Fuller details of experiments will be given in a later paper.

Recent investigations show that *Oemida* can live in many species of wood including hardwoods, that pruned cypress trees in plantations are especially liable to attack and that structural timber of *Podocarpus* continues to suffer; there are reasons to suspect that structural timber of, for example, pine and cypress will be equally liable.

Exotic Conifer Plantations in East Africa

In Kenya, plantations of cypress (mainly *Cupressus macrocarpa, C. lusitanica* and *C. benthami*) were not started on a commercial scale until 1926, although small experimental plantations had been made from 1911 to 1925. *C. macrocarpa*, at first very promising, was in 1951 ruled out for further planting because of its liability to fungal attack. Various other exotic conifers were also planted on a smaller scale as well as the indigenous and much-slower-growing *Juniperus procera, Podocarpus gracilior* and *P. milanjianus*. Kenya aims at planting 210,000 acres of softwoods of which 57,000 acres have been completed; in recent years at the rate of about 7,000 acres per annum. In 1947 it was decided to aim at increasing the proportion of pines to 50 per cent. *Pinus radiata* and *P. patula* have proved successful and certain other species seem promising. Cypress is thinned every two years from the 7th to the 11th and after that at three-year intervals to the 14th, 17th or 23rd year, according to the quality of the locality. Pruning (and this is especially associated with risk of *Oemida*) is done every two years from the 3rd to the 11th; formerly to as high as 30 ft. but limitation to 15 ft. has recently been adopted. The softwood plantations are in the Highlands of N.W. Kenya usually above 6,000 ft. and with a rainfall above 35 in. Although the equator passes through this region the climate is temperate.

Tanganyika has an extensive planting scheme mostly for *Cupressus lusitanica, C. benthami* and *Pinus patula*, and Uganda plans to establish at least 9,000 acres of exotic softwoods mainly in West Nile, Toro and Kigezi.

Recognition of O. gahani

It is not proposed to give detailed descriptions of the stages in this paper but characters now given should help in identification. In any case, it is advisable to send specimens to the Forest Entomologist for confirmation in cases of doubt. However, a Forest Officer, equipped with a x 10 lens, will be able to distinguish the larva after a little practice.

The Adult.—The species belongs to the tribe Oemini of the sub-family Cerambycinæ, family Cerambycinæ. The genus *Oemida* was created by Gahan (in Distant, 1904, p. 106) for the species described by Distant (1892, p. 202; 1898, p. 369) as *Paroeme gahani*.

Eyes closely faceted. Intercoxal process of posternum very slightly dilated posteriorly. Acetabula of front coxæ open to epimera. (These characters apply to the tribe Oemini with numerous genera and species in East Africa.)

In *Oemida* the antennæ are longer than body in male, scarcely longer in female; the first segment is thickened towards the apex and is furnished there with a cicatrix more or less completely limited by a carina. Prothorax with a short obtuse tubercle at the middle of each side and with some weak elevations above. Front coxæ nearly contiguous, separated by a thin vertical lamella. Legs rather long (especially the hind pair) and fusiform clavate with a thin, fairly long, basal peduncle (resembling in form those of *Xystrocera* Gahan).

In *O. gahani* there is some variation in colour. Antennæ reddish with scape and tips of the following segment blackish (but more uniformly dark brown in some). Pronotum dark brown to blackish above, the weakly elevated part usually lighter. Elytra dull brown-testaceous often with longitudinal streaks of infuscation; surface finely, irregularly and rather closely punctuate; apices rounded. Length, 8 mm. to 23 mm.

So far no other species have been described in the genus *Oemida*. Samples of adults reared from various species of wood were identified as *O. gahani* by the late Mr. D. J. Atkinson.

The Egg.—White elliptical, rounded at each end, surface granulate; length variable, mean 1.3 mm. Several eggs are laid together and joined with a mucilage.

The Larva.—In the *Cerambycinæ*: Head wider than long; labrum and clypens not filling space between dorsal articulations of mandibles; mandibles short and gouge-shaped, not oblique at apex.

In the *Oemini*: Ocelli not distinct, legs present and jointed but small. The antero-ventral margin of the head is even (not tuberculate as in *Hesperophanini*). The characters cited apply to several species of the tribe so far examined.

In *Oemida gahani*: The anterior dorsal margin of the head capsule has at most a trace of pigment along the extreme edge (this separates most allied larvæ, which have the anterior margin of the head quite distinctly brown or blackish). Genal setæ are rather long. The dorsal and ventral ampullæ of abdominal segments are distinctly bilobed.

This brief statement is not absolute for when other allied species are known some may prove to be similar. However, if a larva does not have the above characters it is not *Oemida*.

The species will most frequently be found in the larval stage and it is important to avoid confusion with other species. It may be noted that tunnels in growing trees are always internal, not in the peripheral living tissues; in dead logs under-bark galleries are rarely found; in structural timber the whole inside may be almost entirely broken down while the external surface may appear to be fairly sound but with typically oval emergence holes when adults have completed a life-cycle.

Distinction from Chlorophorus carinatus Aur.

This is a species which attacks dying trees and felled logs of many species and is very common in cypress. The larva makes tortuous galleries under bark (compare *Oemida*) and later pupates, typically, within an inch of the external surface of the wood. The damage appears to be of little consequence. The larva, again the most frequently found stage, differs from that of *Oemida* as follows: The anterior margin of the head is very distinctly blackish; a pair of ocelli is present; legs are not distinct and the abdominal ampullæ are not bilobed.

Distribution

In Kenya, *Oemida gahani* has been found widely distributed in all the Highland forest divisions: Nairobi (including Nairobi City), Eldoret, Londiani, Nyeri, Thomson's Falls and Kisumu. The Coryndon Museum has specimens labelled as from Denyang and N. Turkana (Northern Frontier District), Chyula Hills and Mwingi.

In Tanganyika, specimens of the beetle have been taken at Ngorogoro and Ukerewe (British Museum specimens) and at Moshi (Coryndon Museum). Recently a piece of sawn cypress from Lushoto was found to contain larvæ that resembled *O. gahani* as also do larvæ from a 25-year-old standing *Cupressus lusitanica* which had been damaged by a native knife.

There appear to be no previous records of the species from Uganda. However, a collector was sent for a short while to the west (Uganda) side of Mt. Elgon in December, 1952, to search and found larvæ and pupæ resembling *Oemida* in a dry, fallen tree of *Allophylus abyssinica*; one of the pupæ yielded an adult beetle to confirm this record. (The beetle is abundant on the Kenya side of Mt. Elgon.)

The only other locality records are from the Transvaal (Distant, 1904, p. 106) but there seems to be no record after 1904. Mr. F. G. Tooke, Senior Entomologist of the Division of Entomology, Pretoria, has written a comprehensive bulletin on the wood-boring beetles of South Africa: *Oemida* is not mentioned. Mr. Tooke, in answer to a query (1950) answered that he had never come across *Oemida gahani*; later (1952) he wrote: "So far as my experience goes this species has never been taken from dry timber or from standing trees in the Union. Since you first wrote about this species I have been keeping a sharp look out for it". Distant's record remains something of a mystery.

Host Plants

O. gahani is a borer of dead wood although commonly found in living *Cupressus* spp. and in *Juniperus procera* trees that have been damaged by buffalo, elephants, etc. (causing death of part of the stem) or that have been pruned.

O. gahani can complete its life-cycle in living trees (so far *Cupressus* spp. and *Juniperus procera* have been recorded) and in dead wood, the latter including stumps and logs in the forest and seasoned timber. The apparent contrast between living and dead wood is not so great as at first appears for in the living tree entry is effected through dead wood exposed on the surface of the stem: either due to wounds caused, for example, by animals such as buffalo and elephant or scars resulting from pruning. In the latter case oviposition occurs on the scars, the small larvæ moving inwards to the inner ("dead") part of the tree where, in due course, the galleries run up and down the stem.

In living trees, species of *Cupressus* and especially *C. macrocarpa* have been the most to suffer; although it is the custom to prune several other species of conifers and hardwoods in Kenya plantations we have no record of *Oemida* in other living introduced species.

Indications so far suggest that *Pinus* spp. are immune, perhaps due to high resin content and if this is true it is most important.

In living plantation cypress the youngest tree found to be attacked was six years old and that had been damaged by game. *Oemida* has not been found in those parts of the tree bearing living branches.

Species so far recorded as hosts are:—

In living trees: *Cupressus* spp., *Juniperus procera*.

In dead treees, stumps, logs: *Allophylus mastersi*, *Artocarpus integrifolia*, *Cupressus lusitanica*, *C. macrocarpa*, *Dombeya mastersi*, *Eucalyptus* sp., *Fagaropsis angolensis*, *Gymnosporia luteola*, *Juniperus procera*, *Lagunaria patersonii* (exotic), *Olea chrysophylla*, *O. hochstetteri*, *Pinus radiata*, *Podocarpus gracilior*, *Polyscias kikuyensis*, *Pygeum africanum*, *Rapanea rhododendroides*, *Trichocladus malosanus*.

In seasoned wood: *Podocarpus*, heavy beams, etc.,, flooring and shelving; plywood (? Oregon pine) imported from Europe ten years previously and forming part of a cupboard in Nairobi; unidentified wood of a case containing scientific instruments sent from England several years previously.

Further investigations will undoubtedly lead to a very considerable expansion of this list. As a matter of interest, young larvæ inserted in pieces of dry bamboo by us are thriving after several months.

Life History

The adult beetle is active at night and takes shelter from light during the day; however, when disturbed in the day it becomes almost frenzied in its activity when confined, for example, in a glass vessel. It is a strong flier but its range of flight is not known. In Nairobi, beetles remained alive for 12 to 15 days after emergence; one beetle lived for 31 days at Londiani.

Eggs are laid in batches, often of about 20, in crevices and small depressions on the surface of dead wood; in structural timber old emergence holes are frequently used. In living trees the site of oviposition is dead wood caused either by pruning operations or in scars caused by various animals (elephant, buffalo, etc.). The eggs are gummed together by a mucilage; when eggs are laid in a depression such as an old emergence hole, this mucilage forms a covering level with the wood surface. When a female is put in a glass vessel it lays quite readily under pieces of paper or calico (a fact which is useful when eggs are wanted for experiment). The most frequent incubation period is 38 days (Nairobi: January, February) but the range is 36 to 57 days and this may apply even to the same batch of eggs. The highest number of eggs from one female yet found is 131; these were dissected from a virgin female.

When eggs have been laid on pruning scars in living cypress the newly hatched larvæ bore along the enclosed branch stem towards the centre of the tree when it bores up and down the main stem; the living sapwood is avoided and the health of the tree does not seem to be affected. In Juniper, which has a distinctly coloured "heartwood", conditions are similar, tunnels being found also in the surrounding pale tissue which is also presumably "dead" in the sense of not containing protoplasm. When full fed the larva pupates near the perimeter of the "dead" area and in due course the adult emerges to the exterior through a distinctly oval hole.

While in living trees the larval galleries are deeper in the stem this does not apply to dead trees, timber, etc., in which they may be found anywhere, sometimes as underbark galleries (in which case they may be confused with *C. carinatus*).

In structural timber (*Podocarpus*) the whole of the inside may be honeycombed with frass-filled galleries while the external surface remains intact or with relatively few exit holes; there is a tendency for these holes to be away from the light, e.g., in a floor surface they are on the under surface. Individuals from very dry wood are much smaller (8–10 mm.) than those from wood with a higher moisture content.

Duration of Life-cycle

Several experiments were set up in 1950 to find the period from oviposition to emergence of the adult under laboratory conditions. Unfortunately these experiments were maliciously upset* and the results of newly set-up experiments are not yet available. However, in one case adult beetles were placed with an 8-in. length of freshly felled young cypress stem on 13th November, 1950; eggs were seen three days

* The insectary at Nairobi was looted and experiments maliciously raided no less than three times in 1951–52.

later on a pruning scar in a crevice where the living peripheral tissue had separated from the dead wood. This piece of wood was examined in part in September, 1952, and found to be densely tunnelled and with living larvæ and again in November, 1952, when two adult beetles were found. This gives approximately two years from egg to adult under room conditions in Nairobi, the wood having been allowed to dry out naturally and is the shortest period so far recorded. The length of life-cycle must be greatly influenced by the moisture content of the wood and it is possibly less than two years in the living tree. One piece of sawn timber labelled as having been sent from Maji Mazuri to Nairobi in 1946 because of borer attack was found to contain quite large and living, but extremely flaccid, larvæ in 1951. A severe attack was discovered (by a clerk and his chair falling through the floor) in 1950 in part of the *Podocarpus* flooring in the Forest Department offices in Nairobi; the very dry wood could be broken up between the finger and thumb but still contained numerous small *Oemida* larvæ and miniature adults were reared later. It is probable that, in very dry wood, the life-cycle is very greatly prolonged; there are several records in literature of other Cerambycid species with rather similar habits existing as larvæ for 20 years or more under conditions of desiccation. There are indications that there is considerable variation in length of larval period in individuals from one batch of eggs.

Emergence of Adults and Rainfall

A dead stem of *Lagunaria patersonii* (G. 107) badly attacked by more than one generation of *Oemida* was felled and caged in June, 1950. As mentioned under another heading the 3.25 cubic feet of wood have so far yielded 1,354 adults from the cage which was covered from rain above but with wire gauze walls. Monthly emergence totals plotted against monthly rainfall over nearly three years show a striking correlation: in each year there are two peaks for monthly emergence and these coincide (or almost coincide) with the peaks of monthly rainfall in April (long rains) and in November or, in 1950, October (short rains). For example, in April, 1951, with a rainfall of over 200 mm., the emergence was 170; in April, 1952, rainfall, 128, emergence, 112. Although adults appeared in drier months during the first two years, emergence figures were only from 4 to 20 when rain was 2 mm. or less.

Further experiments to test this strong suggestion that maximum emergence increases with the number of rainy days are projected.

Population Density in Wood

In dead wood the population density can be very high, as the following cases will show.

(*a*) A tall tree, *Lagunaria patersonii* (an Australian species), bifurcating from near the ground, was found in the Arboretum, Nairobi (G. 107), one stem dead the other living. The dead stem on felling, was found to be riddled externally with *Oemida* emergence holes and to have very small to large larvæ internally. The stem with a volume of 3.25 cubic feet was sawn into convenient lengths and caged on 7th June, 1950. This cage has, up to the date of writing, yielded 1,354 adult *Oemida*; the total emergence is, of course, much greater.

(*b*) Evans found a standing cypress, dead about four years, in the middle of a plantation at Kitiro. The tree was barked and sawn into 57 1-ft. lengths; emergence holes and larvæ and pupæ of *Oemida* were counted for each length. Evans found that *Oemida* was fairly evenly distributed through the basal 39 ft. of the stem, the highest concentration being 406 per cubic foot at a height of 10 ft., and the average 249 per cubic foot; the highest larva was near the top (diameter. 1.4 in.) at 52 ft.

(*c*) Forester A. R. Moore sent down from Eldoret Division some 5-in. stems of *Pinus radiata* that had been left on the forest floor for two years after thinning. A 3-ft. length was broken up and contained 32 larvæ, 5 pupæ and 2 adults, giving 97 per cubic foot. It should be noted that we have no record of *Oemida* in living pine as yet.

Attack in Plantations

At first, from August, 1950, forest officers were asked to record the percentage of trees attacked when plantations were thinned; counts were based on examination of the cross cuts when the stems were logged and varied from *nil* to 74 per cent (in one case where heavy game damage was prevalent). Young cypress plantations, thinned at 7 years were unattacked except where previous damage by game had been recorded; in older plantations, up to 26 years, a few showed no (noticed) attack but 5–7 per cent was common. *C. lusitanica, C. torulosa, C. benthami* and *C. macrocarpa* are all liable, the last apparently more

so possibly because of its larger branches resulting in slower occlusion of pruning scars.

Juniper plantations at Maji Mazuri, 18 to 26 years old, showed about 12 per cent attack but at Elburgon (12 to 20 years) showed not more than 0.6 per cent attack.

We have very few observations of thinnings in pine plantation and, as yet, no record of a living tree being attacked. A report from Londiani states that 69 trees felled in 1952 in a 21-year-old plantation were all sound and that the pruning scars of 1949 were all occluded.

There are no records of attack so far in plantations of other species, including hardwoods, where it is customary to prune although *Oemida* is common enough in stumps. However, it was soon found that the method of assessing incidence of attack by examining cross-sections at 10-ft. or 12-ft. intervals results in serious underestimation. Counting felled stems at the butt end gives no indication of actual damage and even at cross-cuts every 10 to 12 ft. up the tree does not give anything like a true figure; for example, in 13 trees, no attack was visible when they had been cut into four or five lengths but seven were found to be bored when all were sawn longitudinally.

Attack in an Untended Plantation

Twenty-three trees were felled in two rows in a half-acre cypress plot (Kitiro I) which had never been thinned or pruned. Of these, 19 (or nearly 83 per cent) were attacked. Another 13 trees taken from the adjoining normally thinned and pruned part of this plantation showed seven attacked trees (about 54 per cent). The high *Oemida* incidence in the untended plot can be explained by the suppressed state of nearly all trees, some of which were dead. In a 26–28-year-old plantation (Kiamweri 2 (C)) that had only been pruned to an average of about 6 ft. when young, but had been lightly thinned, there were only two trees (8 per cent) slightly attacked in a row of 25. The trees in this plot were healthy but had large numbers of small, firm, dead branches. *Oemida* were found in a *Lachnopylis* stump on the spot.

Situation and Aspect

No conclusion has yet been arrived at as to the influence of situation upon attack. Adjoining plantations not differing greatly in other respects have been found to have very different *Oemida* incidence; this might perhaps be due to the season of the year in which pruned.

Association of Attack with Other Troubles

The chief cause of attack is pruning operations; next to wounds, leaving exposed areas of dry wood, caused by various kinds of wild game; similar damage may be caused by yoke oxen used for extraction and also by motor vehicles on too narrow tracks.

There appears to be little connexion between fungal attack and *Oemida* attack; some trees have both but as often a log has only one or the other. It has not yet been proved that fire-scorched trees are especially liable although they might well be expected to be so.

Parasites and Predators

Species of the following genera have been reared: *Neostephanus* (Stephanidæ); *Biphymaphorus* (Braconidæ); *Metapelma* (Eupelmidæ); *Alindria* (Trogositidæ); *Isocymatodera* (Cleridæ) and *Bothrideres* (Colydiidæ). These have been examined by specialists (through the courtesy of the Commonwealth Institute of Entomology) and most, if not all, appear to be new species.

In all cases emergences have been from heavily infested wood, in small proportion to the total number of *Oemida* emergences. It is unlikely that any or all of these species are more than mildly beneficial.

Control Measures

Although it is not advisable to prescribe cut-and-dried control measures against *Oemida* in this interim report, some of the lines worth further consideration are now mentioned. There are two aspects of protection, first of the growing forest and second of structural timber.

Choice of Species

Oemida may be taken as ubiquitous in the Kenya Highlands. In the virgin forest it must have been restricted to dead trees and to trees damaged by wild game. It is practically certain that the population density of the insect must have been vastly increased since the introduction of planned forestry: a tremendous feeding ground, so to speak, has been provided by the custom of pruning, by the introduction of certain otherwise promising but very *Oemida*-susceptible exotics (*Supressus* spp. in particular). It will be a matter for consideration whether planting of susceptible species will be an economic proposition if pruning is essential and if doping the scars proves the

only protective measure. Observation so far suggests that pines may be resistant to attack and it may prove wiser in the long run to grow these (and perhaps other species) and to accept timber rather inferior to cypress.

Abolition of Pruning for Susceptible Species

This would result in more knotty timber but could not size of branches be reduced by choice of species and silviculture?* In any case, pruning to height of about 6 ft. is probably necessary for cultural reasons and especially in connexion with control of rats; doping scars to such a height would be a much simpler operation.

Improving Pruning Technique

The pruning scar being the weak spot it may be possible by suitable technique and perhaps by choosing the most suitable time of the year to ensure occlusion before the emergence peak of *Oemida*. (*See* note by the Silviculturist, Kenya.)

Protective Treatment of Scars

The question of protecting scars by treatment with chemicals is under consideration (*see* note by Silviculturist, Kenya). Action of this kind will probably be proved essential, even if laborious and expensive, if pruning of susceptible species is continued. If only basal pruning for future plantations is ruled, the scars will need doping.

Wild Game and Rats

Damage by wild animals is more prevalent in some areas than in others. It may be accepted that any exposure of dead wood will be followed by *Oemida* (not yet proved for pines). We have not yet found *Oemida* directly associated with rat damage to cypresses, although this usually leads to attack by the Scolytid *Phlœosinus schumensis* Egg.

Forest Sanitation

It is to be expected that there will always be some *Oemida* in any forest area but it is obviously desirable to reduce the population to a minimum. Dead standing trees (definitely of cypress and juniper and probably of most other species) maintain a high and cumulative population of *Oemida*. Logs left on the ground after thinnings are at least almost as undesirable. Large stumps of most species are often heavily infested.

Infected Plantations

A disconcerting fact is that most plantations of cypress and juniper are to some extent infected and that some at least are seriously infected. The trees may present a very fine appearance although infestation is revealed on felling, as in thinning operations. When a high incidence of attack is revealed at the sawmill the question of felling the entire plantation should be considered. A heavily infected plantation is only breeding up a high *Oemida* population and in any case the timber yield at the end of the rotation is doubtful. Plantations that for some reason have been insufficiently tended and contain suppressed trees are to be treated with suspicion.

Disposal of Infected Logs

These require rapid elimination. Burning would be one answer, but it would have to be complete and might prove expensive and difficult. Charcoal-making seems at first sight a feasible solution; even if the product were only of moderate value this might prove the most economical solution.

Sawing of Infected Logs

If it is desired to saw infected logs with a view to salvage, infected pieces must be separated; they should be burned at once. However, if considered worth while, there is little objection to these pieces being used for crate-making, etc., provided they are sterilized *without undue delay*, by a chemical impregnation process under pressure.

Structural Timber

Oemida attack in *Podocarpus* structural timber is common enough in Nairobi; it is most probable that cypress and pine will be equally liable. Pressure impregnation treatment will be necessary. It should be noted that the process may be more difficult than for Powder-Post Beetles (which differ in only attacking sapwood) especially for cypress in which deep penetration is not easy.

ACKNOWLEDGMENTS

We wish to thank those Kenya forest officers who from time to time have sent information of great interest; Messrs. Timsales for information and material and the Commonwealth Institute of Entomology for arranging identifications of the various species of insects concerned.

* Dr. Griffith, Silviculturist, E.A.A.F.R.O., tells us that this would mean closer planting, high initial cost of establishment, and probably a longer rotation.

REFERENCES

Distant (1892). Naturalist in Transvaal: 202, pl. 1, fig. 7.

Distant (1904). *Insecta Transvaaliensia* 1:106, pl. 11, fig. 8.

Gahan (1904). *in* Distant 1904:106.

Wilkinson (1939). *in* Annual Report, Department of Agriculture, Kenya 2 (1937) and 2 (1938).

Wimbush (1945). Management of cypress plantations in Kenya. Forest Department, Kenya, Pamphlet 11.

NOTE BY THE SILVICULTURIST, KENYA

The reduction, in 1952, of the maximum height to which *Cupressus lusitanica* may be pruned from 30 ft. to 15 ft., was made on account of *Oemida* damage. It means more than the halving of the length of stem pruned, for the diameter of branch increases with height and the period for complete occlusion of a wound is a function of the diameter. Whereas pruning wounds at 30 ft. may be of 3 to 5 in. diameter and take 10 years or more to heal, no wound at 15 ft. is likely to be of more than 2½ in. diameter, while 80 per cent will not exceed 1 in. and may heal in under 3 years. The length of the occlusion period is as important a factor as the wound diameter.

From 1952, plantations were raised from seed from trees selected for fine-branching habit. This is a measure that will tend to reduce exposure to *Oemida*.

A great reduction of pruning wound area has been effected by replacing *pangas* as pruning tools by pruning saws and anvil-type secateurs. *Pangas* in careless hands double or treble the minimum area of xylem that need be exposed in pruning.

The practice whereby all or part of the swelling at the base of the branch was removed has been shown to confer no advantage in speed of occlusion, while the area exposed is greater.

The following data show that annual pruning would reduce the exposure to *Oemida* below that of the existing biennial schedule. They are from measurements of 45 trees pruned to half height in 1951 and again in 1953:—

Age	Branch Diameters				Maximum	Mean Length of Pruned Stem
	Below ·5 in.		·5 in. and up			
	Mean No. per Tree	%	Mean No. per Tree	%		
					in.	*ft. in.*
3	40	91	4	9	·7	5 3
5	12	40	18	60	11·3	4 11½

Comparisons of wound area and occlusion rates are now being made between biennial and annual prunings, to various fractional heights, starting with crops of ages 2 and 3. The experiments will also show the effects of the various treatments on diameter and height growth.

The effectiveness of measures to reduce pruning wound area, taken and contemplated, is open to doubt because little is yet known of the preferences of *Oemida* for egg-laying sites. The heartwood core of the enclosed branch stub changes to pink after pruning, unlike the white stub of cypress that has not been pruned. If *Oemida* enters only in the periphery of the stub, and not through the core, wound diameter is of less importance as the sapwood of the stub is relatively quickly occluded.

Trials of brush coatings for pruning wounds have yielded a bitumen medium that has remained intact for 19 months. All wounds in a 3-year-old pruning plot were occluded before any sign of breakdown of the bitumen was seen. The bitumen coating has neither cracked nor flaked off, has offered no crevice to egg-laying *Oemida*, and may possibly be repellent. The objections to the use of a brush coating are financial. An acre of 3-year-old *Cupressus lusitanica* at 3 years old presents 28,000 branches for pruning and a wound area of 20 square feet. At 5 years, 19,000 branches and a wound area of 43 square feet are involved. Coating 640 trees at 15 minutes per tree (using the bitumen product) would mean 160 man/hours per acre. A less viscous medium which could be applied by spraying might put coating of wounds within economic bounds.

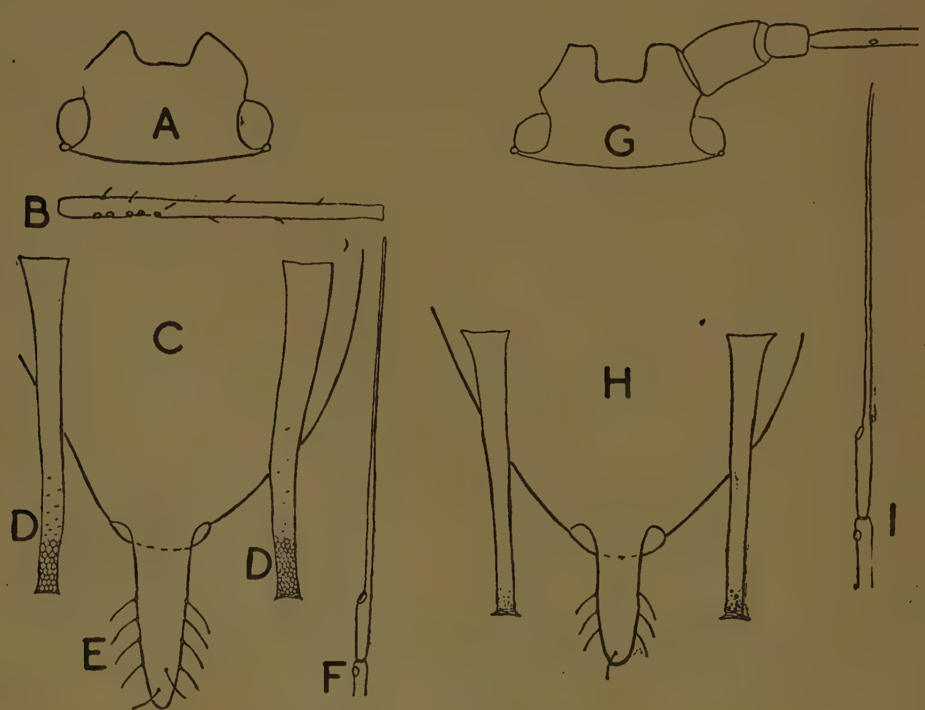
NOTES ON EAST AFRICAN APHIDS II—POLYPHAGOUS SPECIES

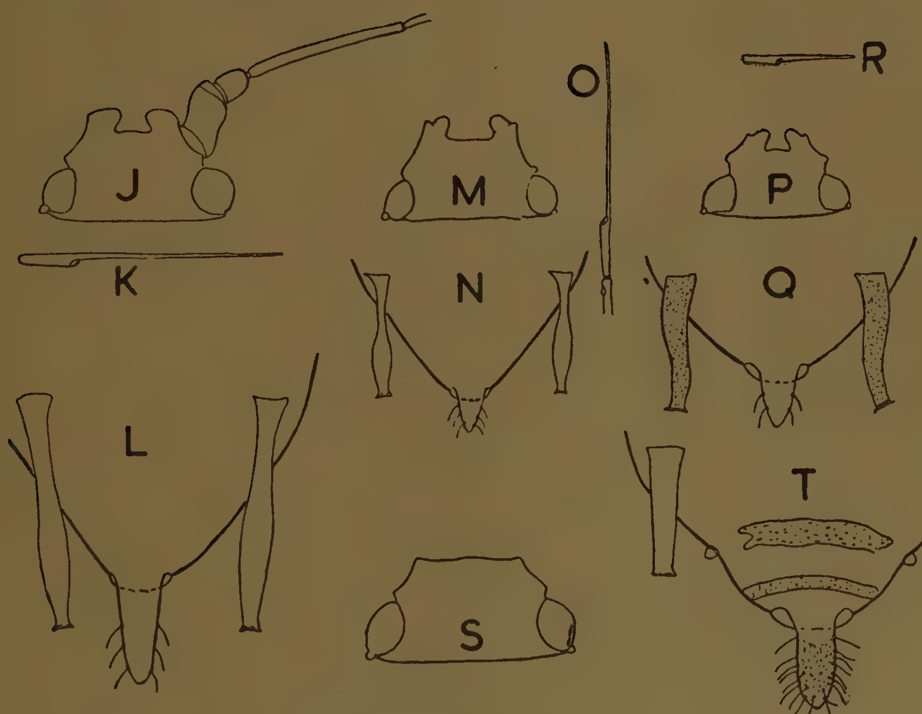
By V. F. Eastop, East African Agriculture and Forestry Research Organization

(*Received for publication on 15th March, 1953*)

Many aphids are highly specific in their choice of food plant, feeding on only one species: others are less specific, feeding on a number of plants, which are, however, often closely related. Eight species are known which show very little specificity and all, in part because of this, are important pests. Six of these species are already known from East Africa, one of the others (*Neomyzus circumflexus*) has an otherwise almost world-wide distribution and the eighth (*Myzus ascalonicus*), first described from England in 1946, has been rapidly extending its range ever since. The last two species are included in this account as it is thought likely that they have either been overlooked in the past or will be introduced in the future. Nothing is said about the biology of these aphids as they may feed on almost any plant and no migration between primary and secondary hosts is not known from East Africa.

All the drawings are to the same scale and are of adults of the wingless form as this is most commonly found. The last two columns of the graphical table give some characters that may be used for the identification of winged forms.





LEGEND

A–F, *Macrosiphum euphorbiæ*, A, head; B, third antennal segment with five secondary rhinaria on basal third; C, posterior end of abdomen showing siphunculi (*d*) and cauda (*e*); F, sixth antennal segment and distal part of the fifth. G–I, *Aulacorthum vincæ*, G, head and antennal segments *I* and *II* and basal part of *III;* H, posterior part of abdomen; I, sixth and distal part of *V* antennal segments. (*N. circumflexus* is not figured as it resembles *vincæ* very closely in the parts illustrated.) J–L, *Myzus persicæ*, J, head; K, sixth antennal segment; L, posterior part of abdomen. M–O, *Myzus ascalonicus*, M, head; N, posterior part of abdomen; O, distal part of V and sixth antennal segment; P–R, *Myzus ornatus*, P, head; Q, posterior part of abdomen; R, sixth antennal segment. S and T, *Aphis fabæ*, S, head; T, posterior part of abdomen. (*A. gossypii* is not shown as, except for the number of caudal hairs, it is very similar to the parts of *fabæ* figured.)

GRAPHICAL TABLE FOR THE DETERMINATION

<table>
<tr><th rowspan="2"></th><th colspan="6">Apteræ</th></tr>
<tr><th></th><th></th><th>Colour in Life</th><th>Shape of Siphunculi</th><th>Secondary rhinaria on third antennal segment</th><th>Number of caudal hairs</th></tr>
<tr><td>Macrosiphum euphorbiæ.</td><td rowspan="6">Lateral abdominal tubercles absent from segments 1 and 7. Spiracles of abdominal segments 1 and 2 placed close together, their pigmented areas almost touching.</td><td>Antennal tubercles well developed with their inner margins diverging distally.</td><td>Green with a paler longitudinal mid-dorsal band.</td><td rowspan="3">Cylindrical or tapering.</td><td rowspan="3">1 to 7 placed in a group on the basal third of the third antennal segment.</td><td>8–12</td></tr>
<tr><td>Aulacorthum vincæ.</td><td rowspan="2">Antennal tubercles well developed, inner sides parallel.</td><td>Green, with a darker green area at the base of each siphunculus.</td><td>6–8</td></tr>
<tr><td>Neomyzus circumflexus.</td><td>Green, with a large U-shaped black mark covering most of the dorsal surface.</td><td>5–7</td></tr>
<tr><td>Myzus ascalonicus.</td><td rowspan="3">Antennal tubercles well developed, their inner sides converging anteriorly.</td><td>Pale greyish yellow.</td><td rowspan="2">Clavate.</td><td rowspan="5">Absent from third antennal segment of apteræ.</td><td>5–7</td></tr>
<tr><td>Myzus persicæ</td><td>Green to olive-green.</td><td>5–7</td></tr>
<tr><td>Myzus ornatus.</td><td>Brownish yellow with small dark brown marks segmentally arranged in pairs on each side of the abdomen.</td><td rowspan="3">Antennal tubercles little developed or absent.</td><td>4–6</td></tr>
<tr><td>Aphis fabæ.</td><td colspan="2" rowspan="2">Lateral abdominal tubercles on segments 1 and 7 well developed. Spiracles of abdominal segments 1 and 2 widely separated, placed on either side of the lateral abdominal tubercle. Antennal tubercles absent.</td><td>Black.</td><td>12–20</td></tr>
<tr><td>Aphis gossypii.</td><td>Grèen, olive, yellow, orange or black.</td><td>5–10</td></tr>
</table>

OF POLYPHAGOUS APHIDS

			Alatæ	
processus terminalis base VI antennal segment ratio	Siphunculi		Dorsal abdominal pigmentation	Secondary rhinaria
About 5	Band of hexagonal reticulation over distal one seventh.		Absent, completely green dorsally.	Confined to the third antennal segment.
About 4	Siphunculi without distal band of hexagonal reticulation.	Siphunculi longer than width of head across eyes.	Abdominal segments with entire or broken black transverse bars which may more or less fuse to form a broken black patch.	
		Siphunculi shorter than width of head across eyes.		Secondary rhinaria present on both III and IV antennal segments.
About 3½		Siphunculi shorter than width of head across eyes and than third antennal segment.	Abdomen always bearing a dorsal black patch.	Secondary rhinaria confined to the third antennal segment.
About 3		Siphunculi longer than width of head across eyes and than III antennal segment.		
About 2		Siphunculi characteristically bent and dark coloured.		
2½–3		Antennal hairs as long or longer than diameter of III antennal segment.	Abdominal segments with more or less developed black transverse bars, never forming a black patch.	Secondary rhinaria either on III only or on III and IV antennal segments, rarely also on V.
		Antennal hairs shorter than diameter of III antennal segment.		

LETTER TO THE EDITOR

PRESERVATION OF CREAM BY WASHING

DEAR SIR,

When in the N. Transvaal, S. Africa, a year or two ago, I tried out an experiment, during the hot season, which may be of some interest to your readers. My communications with a creamery were poor and infrequent, and the putrid condition of cream, of which I used to send in a large quantity, on arrival at the creamery was a source of considerable loss of income. In order to get over the difficulty, I hit upon the idea of washing out all the putrifiable matter from the cream. This was done by adding an equivalent quantity of unheated water to the cream as had been discarded in the skimmed milk, mixing thoroughly, and then reseparating the mixture of cream and water. The butterfat suspended in water, and looking just like cream, came from the cream outlet, and the water mixed with the milk which had originally been part of the cream, came from the skimmed milk outlet. I actually turned in the cream screw for the second separation, so that the suspension tested at about 75 per cent butterfat, at which it was just about as fluid as ordinary cream at 45–50 per cent butterfat. A butterfat test on the watery effluent from the skimmed milk outlet showed the minutest trace of butterfat. The loss is insignificant.

About a gallon of the double-separated product was kept for six weeks, without stirring and uncooled, at an average temperature of about 75° F., and was then sent to the Dairy Department of an Agricultural College to be turned into butter. The odour at the time of despatch was as sweet as that of ordinary well-kept cream after 24 hours from separation, and the taste was like that of fresh cream. The report on the butter was very satisfactory. It was good, but a little flat in flavour, which was to be expected since it was not disclosed that the sample had been double separated. The lack of sugar in its had prevented the formation of lactic acid necessary for ripening. In fact the sample was so fresh and unripe that it was found difficult to churn. It should have been mixed with a quantity of fresh or skimmed milk and allowed a day or two to ripen before churning. Had this been done, a first-class, full-flavoured butter would have resulted.

The second separation must, of course, follow soon after the first separation, otherwise curd clots will block the separator and butterfat loss will occur.

No special purity in the water is necessary. As long as it is pure enough to drink, it is pure enough to use for separation. In order to give the worst possible conditions to the experiment described above, I used furrow water unfit for drinking. But this was a private experiment, and pure water only should be used if the product is sent to a creamery.

One more tip—it is just as well to note the position of the key before alteration is made to the cream screw, so that it may be easily returned to its old position for normal separation. The position at which a 70–75 per cent suspension in water is given from the separator on the second separation should be noted also. Alternatively, two of the disc covers, in which the cream screw is situated, may be kept and suitably marked, one for the first separation and one for the second. Best results are obtained when the bowl is washed between the first and second separations.

Some of your readers may be interested in trying this out, especially those whose distance from a creamery is great and communications infrequent. There may be others who are now too far from anywhere for normal cream production, but who, by this method, could successfully send in batches of first-grade cream every fortnight or even month.

If the creamery manager is in any doubt about the process, ask him to contact the National Institute for Research in Dairying, Reading, U.K., for particulars of their trials, and he will be left in no doubt whatever.

Yours faithfully,
V. O. GOUMENT.
23-1-53.

New Dryburn,
Bowsden,
Berwick-on-Tweed,
England.

PRELIMINARY TRIALS OF SOFT FIBRE PLANTS IN KENYA

By M. S. Nattrass, Department of Agriculture, Kenya

(*Received for publication on 17th April, 1953*)

In 1952 a series of observation plots was established for the purpose of making preliminary tests of fibre plants using both indigenous and exotic species and varieties. The plots were situated in all parts of the Colony at altitudes varying from coast level to 8,200 ft. and can be divided into low-, medium- and high-altitude stations. In the first area are included the two coast stations at Matuga and Kibarani, and Kisumu 3,800 ft. on Lake Victoria. The medium-altitude stations are the Scott Laboratories at Nairobi; Embu, Fort Hall, Kisii, Kakamega and Kitale; and the high-altitude stations over 6,500 ft.—Njoro, Eldoret and Molo. Unfortunately, the rainfall for 1952 was patchy over all areas, and on some stations drought greatly hampered growth at a vital stage.

The observation plots were small and the land was dressed, in most cases—but not all—with farmyard manure and phosphates. Planting was done in drills 18 in. apart and the plants subsequently thinned to 3 in. apart. This is about twice the width of spacing normally recommended for cultivated *Hibiscus* spp. but was done to facilitate weeding and so ensure freedom from competition. Closer spacing would probably give higher yields.

With regard to planting time it was found, in the "long rains–short rains" area, that planting in the "short rains", i.e. mid-November–December, provided the rainfall was sufficient for the plants to get away, with the long, sunny period following, was the best time. Plants from seed put in the "long rains", i.e. mid-April–May remained small and stunted until the warmer weather. This was particularly noticeable with the exotics sent via South Africa. These plants were more susceptible to disease than the indigenous species, being attacked by *Botrytis cinerea* canker and *Fusarium* root rot.

Of the indigenous species of *Malvaceæ*, *Hibiscus cannabinus* L. from Kitale is the best and is quite promising. This grew vigorously in Kitale—in the wild state, and in Nairobi, under cultivation, reaching 11 ft. in 4–5 months. It has single, nearly unbranched stems which are practically unarmed, and was free from disease. The air dry stalks yielded 27.1 per cent of dry fibre. No satisfactory figures for the yield per acre have been received. Two other local strains of *H. cannabinus* are also promising. The Rongai strain grows vigorously, is practically unarmed, and matures in 4–5 months. It yielded approximately 320 lb. of dry-brushed fibre per acre at Rongai. That from Sultan Hamud has not yet been properly tested but in growth and habit resembles the two preceding strains.

Two others from Makueni and Fort Hall were less promising but warrant further trial on a larger scale. Nine other species of *Hibiscus* were tried, but the only one to show promise was *H. greenwayii*. This is probably a perennial as it took 12 months to reach maturity. Retting has not yet been completed. Growth and habit were very much like the next species, *Malva verticillata*—except that this latter is a quick grower reaching 10 ft. in 5–6 months. It produces a high yield of fibre, but the butt ends caused some difficulty in retting, and further tests will have to be done. The fibre of the upper part appeared to be good.

Two *Abutilon* spp. which are also perennials, have not yet reach maturity.

Two strains of *Urena lobata* were tried, but neither the Congo strain, nor the local one, grew satisfactorily at any of those stations where it was on trial. The seeds are contained in carpels which have the disadvantage of possessing hooked bristles on the outside. These stick together and are almost impossible to separate for sowing unless treated by acid or scarified [1]. A small experimental plot at the Scott Laboratories was wiped out in 1950 by severe stem canker caused by *Botrytis cinerea* [2]. *Pavonia schimperiana* grew well but tends to branch throughout its length, and it is not known whether its fibre is suitable [3].

Furcraea gigantea, Agavaceae was grown at Kakamega but has not yet reached maturity.

Of the exotic species, *H. cannabinus* from Nigeria, Florida and Cuba were the most promising and grew to about 6 ft. *H. cannabinus ex* Nigeria at the Scott Laboratories has produced a second crop. The first crop was cut for fibre just before the rains broke in November, 1952, and seed was harvested in February, 1953, from the second crop. *H. cannabinus ex* Florida grew well both at Kitale and Nairobi. *H. cannabinus ex* Cuba was severely attacked by the fungus *Glomerella cingulata* which was almost certainly seed-borne and would probably respond to seed disinfection. Two others of promise were *H. cannabinus* var. Egyptian Teal from Southern Rhodesia and *H. cannabinus* var. El Salvador sent via South Africa. The leaves of the latter were attacked by mildew (*Oidium* sp.) but this had no adverse effect on growth.

Aphids were a pest on some of the plots at certain times of the year but were easily controlled by spraying. Cotton stainers (*Dysdercus* sp.) were also a common pest and in some cases interfered with seed production.

Of the indigenous varieties mentioned above *H. cannabinus* is found growing wild at all altitudes, *Pavonia urens* at the higher altitudes, *Malva verticillata* and *Pavonia schimperiana* at high and medium altitudes and *H. greenwayii* from the coast to 3,000 ft. This last grew well at the Scott Laboratories but flowering was spasmodic and seed did not set on those plants which flowered. In all the indigenous species germination was much improved by treatment of the seed with concentrated sulphuric acid before sowing.

SUMMARY

In spite of the unsatisfactory weather conditions these results show that some of the species are worth further trial, notably the three and possibly five indigenous varieties of *H. cannabinus*; five exotic *H. cannabinus*; *H. greenwayii* and *Malva verticillata*. *Pavonia schimperiana*, and *Pavonia urens* which is very similar, might also be included.

If the fibre quality is satisfactory, these would appear to have a good chance of being a commercial proposition.

Satisfactory methods of decorticating or retting the fibre are not immediately available, but it is likely that they would be by the time Kenya is ready for planting on a commercial scale.

Although the position with regard to jute is no longer acute, the department will, during 1953, undertake a more thorough testing of these other fibre plants which have shown promise. Observations will be made on the times of planting and harvesting; spacing and other data, at the various stations in the Colony, so that, should the necessity again arise, practical advice on the cultivation of these alternative fibres will be available.

REFERENCES

[1] Haarer, A. E. "Congo Jute and its Potentialities." World Crops, 5-2-1953.

[2] Nattrass, R. M. "A *Botrytis* Disease of *Urena lobata* in Kenya." *E.A. Agric. Journal*, Vol. XVI, No. 4, 1953.

[3] Ferrell, A. J., and Jarman, C. G. "*Pavonia urens* Fibre from Uganda." Colonial Plant and Animal Products, Vol. 2, No. 4, 1951.

A NOTE ON MITES AS NEW PESTS OF COFFEA ARABICA IN TANGANYIKA

By R. G. Tapley, Department of Agriculture, Tanganyika

(*Received for publication on 15th April, 1953*)

During 1950 a number of coffee trees at the Coffee Research Station, Lyamungu were showing an unusual form of leaf distortion which was attributed to the Aphids frequently found on bursting leaf buds. Later as the damage became more extensive a closer study was made and several species of minute Acarina (mites) were observed, often in large numbers on the underside of young foliage.

A sample of mites was taken from Lyamungu and these were examined by Dr. Owen Evans of the British Museum who found three species of phytophagous mites and several species of predaceous mites. The mites which were probably causing the damage were identified by Dr. Evans as:—

Hemitarsonemus latus (Banks) Fam. Tarsonemidæ.

Brevipalpus phœnicis (Geijskes, 1939) Fam. Phytoptipalpidæ.

Tydeus ? caudatus (Ant. Dugès) Fam. Tydeidæ.

H. latus is the most important pest and can usually be found in large numbers on affected trees. The other two species are comparatively rare.

H. latus is cosmopolitan in distribution and has been recorded as a pest in N. and S. America, the West Indies, S. Africa and Ceylon on several economic crops, including tea, avocado pear, bean, castor and tobacco, as well as on ornamental plants and weeds [2] [4]. This is believed to be the first record of its incidence on coffee. Gadd [3] gives an account of the biology of *H. latus* on tea and much of his data is pertinent to the mite on coffee.

B. phœnicis is known in the Argentine, Malaya and New Zealand as a pest of several economic crops including rubber trees and citrus [5].

On coffee the mite is light green in colour and lives on the underside of young and developing leaves where it feeds on the epidermis, mostly near the mid-rib and veins. Microscopic examination of damaged leaves shows that the epidermal cells are punctured and some of their contents extracted. The affected cells die. Rarely the sub-epidermal cells are also affected. Where extensive areas of epidermal cells are damaged the sub-epidermis becomes meristematic and forms several layers of cells which thicken and die, forming a protective scar tissue. This tissue is raised above the leaf surface.

A normally developing leaf grows over its whole area, the lamina increase in thickness and area while the veins lengthen and thicken. However, when a leaf has been severely affected by mites and areas of dead scar tissue are formed to replace the injured epidermis, normal growth is restricted in the scar areas while the undamaged areas grow normally. This naturally results in the leaf becoming increasingly distorted with growth and frequently results in a split, not only between cell layers within the leaf, but in the leaf as a whole. Severely damaged leaves never reach maturity, but remain dwarfed, distorted and torn.

The only known severe outbreak has occurred on certain plots of unshaded, single-stem coffee on the Coffee Research Station. Some trees within the outbreak areas were almost totally affected, while on others the damage has been limited to certain parts of the tree or even to a few isolated branches. *H. latus* is believed to be widespread in the Northern Province of Tanganyika and has certainly been observed on some of the trees of the off-station Coffee Research Station selection trials.

The cause of the outbreak is not known. It is possible that the use of D.D.T. emulsion now universally used against *Antestia* and thrips has been an important factor and certainly many parallel cases are known where the use of persistent organic insecticides has caused major outbreaks [1]. For the present and until more is known about the biological complexities, it would be advisable to avoid the use of D.D.T. in favour of pyrethrum wherever an outbreak is known to occur.

Since it is probable that the mite populations will be able to increase rapidly under the ecological conditions met with in most of the coffee-growing areas of Tanganyika, and that *H. latus* thrives on bursting buds and new leaves only, it will be difficult to effect their control chemically and at an economic price. It is therefore essential to control the pests by cultural means and the possibilities of doing this will be investigated as soon as possible.

REFERENCES

[1] Brown, A. W. A. "Insect Control by Chemicals." Wiley, 1951, p. 738.

[2] Ewing, H. E. U.S. Dept. of Agric. Technical Bulletin No. 653.

[3] Gadd, C. H. Bull. Ent. Res. U. 37, Pt. II, p. 157, 1946.

[4] Lavoipierre, M. M. J. J. of Ent. Soc. of S. Africa, V. 3, 1940.

[5] Pritchard, A. E., and Baker, E. W. Univ. of California Publications in Entomology. V. 9, No. 1, pp. 1–94, 1951.

SYMPOSIUM ON INSECTICIDES AND COLONIAL AGRICULTURAL DEVELOPMENT

(*Held at Manor Hall, Clifton, Bristol,* 23*rd*–27*th March,* 1953)

The Colston Research Society, an association of Bristol citizens formed to support research in the University of Bristol, has in recent years arranged Symposia on research topics of current interest. Eighty invited members took part in the 1953 Symposium, which dealt with insecticides in relation to colonial agricultural development. The conference had the support of the Colonial Office and the Agricultural Research Council and was directed by Professor T. Wallace, C.B.E., F.R.S., Director of the Bristol University Agricultural and Horticultural Research Station at Long Ashton.

In the opening session, Dr. W. J. Hall, C.M.G. (Commonwealth Institute of Entomology) stated that the 38 British colonies, covering 2¼ million square miles and supporting 70 million inhabitants, employed only 29 entomologists. In 1949 the total value of crops exported from the colonies was £182 million: it was impossible to say how far this could be increased by the control of pests but, as an example, it was known that the control of cotton jassids in the Sudan had given a return of over £4 million for an expenditure of £200,000. Dr. Hall referred to the coming expiry of the Colonial Development and Welfare Act in 1956 and hoped that ample funds would be made available to continue the pest control research work initiated by that Act.

Mr. C. B. Symes, O.B.E., of the Colonial Office, outlined the existing insecticide researches in the British colonies, emphasizing the uses of the chlorinated hydrocarbons in the control of pests of food crops. He pressed for an increase in fundamental work on the specific pests and environmental problems encountered in the colonies.

Mr. S. Callaway, of the Chemical Defence Experimental Establishment, Porton, described the species and distribution of locusts and gave a detailed account of an air-spraying operation in Tanganyika using a spray of 20 per cent dinitrocresol in oil. In the sprayed area 4½ million locusts (96 per cent of the original population) were destroyed, using 3½ tons of diluted insecticide.

Mons. G. Bouriquet, of the French Colonial Service, detailed the organizations set up to control locust attacks in French West Africa and in Madagascar. In these areas the insecticide chiefly used was a 25 per cent B.H.C. dust.

In the course of the discussion, Mr. E. R. Hoare called for better co-operation between the entomologist and the engineer. Mr. M. J. Way questioned the value of insecticide applications on peasant holdings, where pests were usually much less damaging than in plantations, but Mr. G. Swaine noted the exceptional case of native-grown maize, which was more heavily infected with borer than the plantation crop.

Sir Harold Tempany pointed out that the yields of peasant holdings were exceptionally low and must be increased because population was outpacing food production. Such increase could only be obtained by some measure of control of cropping exercised willingly by the native cultivators. The problem was mainly political and administrative but could not be evaded. Mr. Leyland Cole mentioned the promising results given by aldrin in locust control and Mr. R. J. Joyce looked to concentrate sprays to reduce the high transport costs of anti-locust campaigns. Dr. W. F. Jepson asked for improvements in the simplest hand methods

of spraying and pointed out that colonial authorities were ready to finance practical schemes of research on pest control.

Mr. K. S. McKinlay described the difficulties imposed by staff shortage in applying existing knowledge to peasant agriculture. Professor J. W. Munro noted the improvement in recruitment of applied entomologists, and pleaded for more vacation courses for undergraduates at research institutes. Dr. R. A. E. Galley commented that the Ministry of Labour forecast a surplus of general biologists, although there were not enough specialists available: he advocated changes in the methods of training. Mr. W. T. Cowan, replying to Sir Harold Tempany, noted that co-operative societies of cotton growers were developing in Uganda and that Africans were starting to own ginneries, which gave them a direct interest in increasing cotton yields.

Opening the afternoon session of 24th March, Mr. E. O. Pearson (Empire Cotton-growing Corporation) named cotton as the principal cash crop in the arable farming of the African. He pointed out that there was only one instance in Africa—the control of jassid on irrigated cotton in the Sudan—where insecticide applications had reached large-scale commercial use. In the rain-fed areas, chemical control might possibly be attempted against American bollworm in eastern Tanganyika and against *Lygus vosseleri* in parts of Uganda and the Congo. The use of insecticides on peasant-grown cotton awaited a more orderly system of farming and an increase in basic yields by improved cultivation and manuring.

Mr. K. S. McKinlay (East African Agriculture and Forestry Research Organization) showed that the conventional design of small field plots was unsuitable for *Lygus* control studies. He described a method using weekly spraying of individual plant rows with D.D.T. and toxaphene to provide insect-free plants for comparison of their yields with those of surrounding *Lygus*-attacked areas. Mr. McKinlay considered that the inevitable delay in extending the use of insecticides to peasant crops gave the entomologists time to devise efficient treatments.

In the discussion, Mr. G. Swaine suggested that Mr. McKinlay's figures on insect-caused crop losses should be widely publicized among colonial administrators. Mr. Joyce listed direct effects of D.D.T. on cotton plants in the Sudan—increased leaf area favouring whitefly development, and retarded fruiting following the suppression of jassid-induced premature boll formation. Dr. Jepson suggested a plan for reducing American bollworm by segregating cotton from maize in peasant cultivation.

In comparing U.S.A. with African cotton-growing, Mr. Pearson recorded that U.S. yields, being ten times greater than those in Africa, could carry a much higher cost of spraying. Answering Sir Harold Tempany, Mr. Pearson said that toxaphene was approximately equal to D.D.T. in bollworm control.

Mr. Cole deprecated the use of over-crude methods for applying the potent modern insecticides. He called attention to the use of aldrin, dieldrin and endrin in cotton pest control.

Mr. Cowan suggested that co-operation of peasant cultivators could be anticipated in the future and mentioned developments in the Congo. Mr. Pearson explained that in the Belgian Congo a much greater degree of direct control of agriculture was adopted than would be tolerated in British colonies. Mr. Emery considered that the peasant cultivator who wanted higher yields would plant a wider area rather than buy a sprayer.

Mr. Joyce advocated more use of air-sprayed concentrates even on peasant holdings, but Mr. Pearson pointed out that what was feasible in the Gezira was impracticable elsewhere in Africa. Mr. McKinlay concluded that the peasant cultivator could be taught to use insecticides but that it would be a long process and by no means a cheap and easy solution to colonial crop problems.

On the second day, with Sir Harold Tempany in the chair, the first paper was given by Mr. G. Swaine (Department of Agriculture, Tanganyika), who recorded that treatment of cotton with 10 per cent D.D.T. plus 3 per cent B.H.C., applied five times, greatly increased yield by controlling American bollworm. On coffee, the Pentatomid bug *Antestia lineaticollis* was now widely controlled in East Africa by D.D.T. emulsion. Contact insecticides had given striking results when applied as seed dressings or mixed with the soil: e.g., B.H.C. against termites or sugar-cane white grubs; aldrin and B.H.C. against the wheat pest *Heteronychus consimilis*; and toxaphene against cutworms.

Mr. M. J. Way (Rothamsted Experimental Station) described certain ecological balances between pests and predators that might be adversely affected by insecticides. In Zanzibar

the *Theraptus* bug attacking coco-nut palms was often kept in check by a predatory ant. This ant, however, encouraged the mealy bug suspected of being the vector of a virus attacking clove trees. A similar relationship between ants and mealy bugs existed on cacao in West Africa.

Mr. J. Bowden (Agricultural Department, Gold Coast), in a paper on some West African crop problems, dealt principally with pests of the native-grown food plants, maize, sorghum and millet.

In the discussion, Dr. Jepson noted that the dosage of B.H.C. for white grub control in Tanganyika was 8 oz. of a proprietary material per 50 ft. run of furrow at planting. He asked for information on groundnut pest control. Mr. Swaine replied that systemic insecticides rendered plants aphicidal for about 40 days, and seed treatment with schradan gave 15 days' protection. Mr. Joyce noted the effectiveness of B.H.C. against cockchafter grubs in soil but Dr. Jepson added that this was an inhibition of feeding, not an insecticidal effect.

Dr. W. J. Hall, answering Professor Munro, said that *Pseudococcus njalensis*, the principal vector of cacao swollen-shoot, was indigenous to West Africa, but two minor vectors occurred in both West and East Africa.

Mr. L. W. Cole, remarking on the residual effects of insecticides, suggested that incorporation with soil might be more effective than seed dressing, but Dr. Holmes stated that seed dressing with B.H.C. used only one-tenth of material compared with broadcasting and still showed residual effects. Mr. Hoare noted that machines placing fertilizers beneath seed crops were now available.

Mr. Greenwood showed that dwarf sorghums could not be successfully introduced into northern Nigeria unless stem borer could be controlled. Mr. Bedford listed some of the disadvantages in using dusts for cotton pest control.

Mr. Thompson instanced examples of co-operation between entomologists and local populations on tsetse and locust control. Mr. Swaine concluded with a comment on phytotoxic effects of B.H.C. on tobacco seedlings in Rhodesia.

In the afternoon, a paper by Mr. R. G. Fennah (Imperial College of Tropical Agriculture, Trinidad), was read by Mr. D. B. Murray. Mr. Fennah considered that the inefficiency of West Indian agriculture was of overwhelming importance compared with the toll exacted by insects. The successes that had so far attended the use of insecticides in the British Caribbean territories were the suppression of the sugar-cane frog-hopper in Trinidad and the simplification of parasol ant control. The most obvious lacuna was the absence of effective chemical protection of citrus against fruit-puncturing moths.

Professor J. W. Munro (Imperial College of Science) warned the Conference that the transfer of native labour from subsistence agriculture to industry brought famine nearer, unless satisfactory storage of foodstuffs could be provided. Much knowledge on fumigation and other methods of infestation control was available but the urgent need was to use this knowledge. He called for improvements in storage and transport methods to facilitate control and emphasized the importance of training selected Africans and West Indians as technicians in the practice of storage pest destruction.

In the discussion Mr. May suggested that the accumulation of food stocks necessitated a replacement of bulky non-storable products such as bananas and sweet potatoes by grain. Dr. Jepson hoped that the development of agriculture as a subject for study in African universities would be encouraged by providing sufficiently attractive posts in agriculture for trained Africans. Mr. D. W. Hall asked for more research on methyl bromide fumigation, design of equipment and methods of underground pit storage. Mr. Turtle recorded that the Infestation Control Division of the Ministry of Agriculture had given training to 50 African produce officers.

Dr. Fisher called attention to infestations of timber and outlined the activities of the West African timber-borer research team, appointed by the Colonial Office to study infestation in logs before export. Dr. Fisher also reported on the use of D.D.T. and B.H.C. in plywood glues.

Dr. Coyne referred to the work of Dr. Giglioli in British Guiana where a large increase in the rice-growing area had been made possible by anti-malaria spraying.

Dr. Jepson described the methyl bromide fumigation of the groundnut "pyramids" at Kano as an outstanding example of co-operation between scientific research organizations, the mercantile community and the local control units in Nigeria.

Mr. Swaine described the pit storage in Tanganyika which depends on the hermetic sealing of a bulk of dried grain which by its respiration produces enough carbon dioxide to act as a fumigant. In such pits, rice weevil infestation had been eliminated.

Mr. Emery stated that bagged grain could be protected by suitable impregnation of the sack if the demand for such treatment was sufficient. Mr. McKinlay complained of conflicting statements on permitted tolerances of insecticides in grain and Dr. Galley replied that the Toxicology Committee of the Medical Research Council now recommended a maximum permissible figure of 2.5 p.p.m. gamma-B.H.C. The tentative recommended tolerance for D.D.T. was 7 p.p.m. In U.S.A., D.D.T. was not permitted on foodstuffs. Dr. Coyne pointed out that D.D.T. could, in U.S.A., be employed in homes but not in cow stalls.

The morning session of the last day of the Conference was under the chairmanship of Dr. A. W. Stableforth. The first paper, read by Professor Blakemore, was a general review by Sir Thomas Dalling (F.A.O., Rome), of the insect-transmitted diseases of livestock in colonial territories. This was followed by a film and paper by Dr. J. Carmichael, C.M.G., describing tsetse control work, particularly in Zululand, where applications of D.D.T. aerosols have been regularly made from Anson aircraft fitted with special booms. The droplets emitted were approximately 70 microns diameter, the swathe width 55–70 yards and the deposition approximately 0.25 lb. per acre. After seven such applications in the period September, 1950, to January, 1951, the percentage reduction in tsetse flies was 98.5 per cent for *Glossina morsitans*, 97 per cent for *G. swynnertoni* and over 99.9 per cent for *G. pallidipes*. The numbers showed no tendency to rise in the ensuing nine months although it could not yet be claimed that tsetse was eliminated in the treated area.

Mr. H. E. Harbour (Cooper Technical Bureau) dealt principally with the control of ticks on livestock. The earlier treatments had been chiefly sodium arsenite dips, which were now losing favour partly because of the appearance of arsenic-tolerant tick populations. In recent years D.D.T., B.H.C. and toxaphene had made great contributions to tick control: toxaphene had the advantage of conferring residual protection on cattle. In two areas in Tanganyika tanks had beeen installed and compulsory dipping instituted. As substitutes for dips, spray "tunnels" were proving effective.

The discussion was opened by Dr. J. C. Matthysse (Cornell University, N.Y., U.S.A.), who had just returned from a year's work on ticks in Northern Rhodesia, carried out under the auspices of the Mutual Security Agency. Dr. Matthysse dealt principally with the equipment used for pen spraying of cattle and described the work done by itinerant spray teams in Rhodesia. Mr. Symes raised the question of the relation between duration of residual toxicity and formulation of insecticides. Dr. Matthysse replied that the more intensive light effects in Africa led to shorter residual action than in U.S.A. Mr. Harbour noted that residual effect on cattle was less than on sheep and mentioned that dieldrin showed penetration into the hair cell. Dr. Carmichael considered that the criterion of tsetse fly eradication must be the absence of trypanosomiasis on cattle introduced into the sprayed area. Mr. Courshee asked how a median droplet diameter of 70 microns was obtained and how great was the recovery of emitted material. Mr. Symes replied that the droplets were obtained as a result of the designing of pumps and nozzles at Porton to give this specific result.

Dr. Martin suggested that the cost of derris treatment against warble flies might be lowered by the use of synergists. Dr. Allen Campbell referred to the low toxicity of toxaphene against ticks and Mr. Harbour replied that there were numerous reports on trials under standard conditions but the literature was very scattered.

Dr. Page pointed out that the disappearance of B.H.C. from hairs of cattle was largely due to evaporation, not irradiation: with D.D.T. and possibly other chlorinated hydrocarbons, the effect of light was the main cause of breakdown.

Mr. Harbour, answering Dr. Coyne, suggested that resistance to insecticides was a factor innate in the species and was neither promoted nor checked by any practicable level of dosage.

The final afternoon session, with Mr. H. J. Jones in the chair, was opened by Dr. H. G. H. Kearns (Long Ashton Research Station) who stressed that the successful solution of a spray problem must take into account the biological requirements, the spray material, the culture of the crop, the user and the machinery.

Active, exposed insects such as locusts and capsids were relatively easy to kill; other pests such as red spider required special spraying techniques to ensure complete foliage cover and wetting. Present designs, particularly of manual sprayers, were capable of much improvement but low-priced standardized designs could only be produced if large numbers were required.

"Air-flow" mist sprayers could be used for drift spraying only in exceptional cases such as in locust control: for tree spraying large volumes of air and a higher volume of spray were necessary. A power duster designed at Long Ashton was now being widely used in Africa. Appreciation by the engineer of the biologists' problems was essential in the development of satisfactory spraying equipment.

Dr. E. Holmes (Plant Protection, Ltd.) summarized the magnitude and cost of the search for new insecticides and referred to the difficulties connected with the formulation and analysis of present-day products. He pointed out the necessity for the overseas user to give the manufacturer ample time to ship materials to ensure their arrival when required. Dr. Holmes mentioned the prolonged delays in erecting new plant and the consequent need to anticipate demand some three years ahead. He pointed out that certain insecticides in the U.S.A. had been overproduced with consequent disturbance to the world market. He emphasized the benefits that were accruing from the closer co-operation between official research workers and those from industry.

In the discussion Mr. Higgins mentioned that the training of entomologists at Imperial College included instruction in the use and maintenance of spray machinery. Mr. Hoare emphasized the necessity for obtaining exact data on droplet size and deposition. The National Institute of Agricultural Engineering had now developed an electronic spray deposit analyser and it was hoped that this would be used on a co-operative basis in overseas trials. Mr. Cole noted that manufacturers have also had to develop analytical techniques for determining spray residues and mammalian toxicities. Professor Munro noted that engineering firms were not usually interested in producing simple fumigation equipment. Mr. Joyce described experiments with low-volume spraying in the Sudan, applying 25 per cent D.D.T. concentrate at just over ½ gal. per acre. Mr. Symes considered that until formulations of insecticides and designs of machinery were based on much more fundamental research, there would be much guesswork in pest control procedures. Dr. Kearns, in conclusion supported this contention and said that exact data on the insect-plant relationship must form the basis for intelligent spraying.

Throughout the Conference, the outstanding value of co-operation between home and overseas workers was apparent, and it was made clear that one of the pressing tasks in colonial entomology was the problem of reconciling peasant agriculture with modern methods of pest control.

R. W. MARSH.

REVIEWS

THE PATHOLOGY OF THE TEA PLANT

The diseases and pests of the tea plant, *Camellia sinensis*, have been described and commented on in a long series of scientific papers and technical reports, but a reasonably comprehensive description of what is known about them at a given time appears only about once in a generation. Watt and Mann's "Pests and Blights of the Tea Plant" appeared in 1903 and described in detail some 12 diseases. Those were spacious times with no restrictions on paper. Petch's "The Diseases of the Tea Bush" was published 20 years later and has since been the only detailed work on the subject. It deals with 68 diseases, mainly fungal, and combines field description of symptoms and control with detailed mycological accounts of the causative fungi. But even a book by so distinguished a mycologist as Petch hardly meets the need after an interval of 30 years and, since, moreover, Petch's monograph has been out of print for many years, a more up-to-date account was overdue.

Gadd's monograph of 1949 was a welcome supplement to Petch and was informed with the same essence of scholarship and practical knowledge, but it dealt only with the commoner diseases and was a departmental publication. The initiative has now, after a long period, reverted to the Indian Experiment Station at

Tocklai in the form of a new book entitled "Tea Pests and Diseases and their Control" by E. Hainsworth (W. Heffer & Sons, Ltd., Cambridge, Sh. 18).

As indicated in the title, this is an essentially practical manual with just enough scientific descriptions to help in identification, and with a minimum of scientific terms, which, however, when used, are usually defined (a rather startling exception is the use on the first page of the word "ecdeises", the technical term for the moultings of certain types of young insects during their growth to maturity). Thirty-five fungoid diseases are listed and 41 pests due to "insects" (in the commonly used sense) and parasitic worms. The classification is according to the parts of the plant affected. The exposition is clear and simple with particular attention to control measures. The sub-title indicates that the book has special reference to NE. India but it is nevertheless a valuable manual for use in other tea districts. In Africa, fortunately, diseases are few at present but it is almost inevitable that as the age and area of plantations increase, pests and diseases will increase.

Two features of this book are of special importance, especially in Africa. The first refers to the training and maintenance of a permanent root disease control gang (p. 33 *et seq.*) continuously employed in diagnosis and removal of infected bushes. As Mr. Hainsworth says, every bush on an estate is seen at intervals of approximately a fortnight, and removal of dead or dying bushes should be done as soon after symptoms appear as is possible. Disease organisms travel faster through dead tissues than live and thus increase the rate of infection.

The second feature is the insistence on vigorous sanitation measures to remove infected branches and to lessen the chances of infection after pruning or accidental branch breakage. The standard of pruning is important: an examination of cases of wood rot of frames shows clearly how much of this trouble proceeds from old snags or rough pruning cuts. Mr. Hainsworth makes the valuable point that prevention of disease can to a great extent be secured by cultural means. In East Africa as a whole adequate counter measures against such disease as exists are not well integrated. It is by no means uncommon to find that the cause of a bare patch of land has been casually ascribed to a "hut site" which on closer examination turns out to be an ever-widening attack of Armillaria root disease that is receiving no attention.

East African readers will be surprised to find Mr. Hainsworth saying that adequate plant protection costs *only* Sh. 45 per acre (italics mine). In Ceylon, protection from blister blight alone is costing between Sh. 60 and Sh. 140 per acre. The estimate in this book for the maintenance of a root disease control gang (the most urgent need in East Africa) is Sh. 7 per acre.

Diseases seldom behave in an exactly similar manner in different countries. Armillaria is not mentioned except in a table of diagnostic characteristics, because it is of little importance in NE. India. A further example of the same kind is the shot-hole Borer of Tea (*Xyleborus fornicatus*) which is so prevalent in Ceylon that the inevitable branch breakages cause marked diminution of crop. On a manurial field experiment they masked all responses to fertilizer until the third year of the pruning cycle, at which stage the wood was too lignified or otherwise unpalatable to attract the borer.

The eelworm, *Heterodera marioni*, is widespread in East Africa. When a green manure crop is used either as shade or as a preparation of the ground before nursery planting (p. 10) the species used should be one not highly susceptible to *Heterodera* attack. In this respect both *Tephrosia candida* and *Tephrosia volgelii* are unsuitable. *Crotalaria anagyroides* meets the need. Both *Nectria lucida* and *Nectria ochroleuca* are known in Kenya and in comparison with NE. India their virulence is reversed, the former attacking live, the latter, as far as observation goes, only dead tea. Other attacks which are more virulent elsewhere are those of *Cercosporella theae* (*Calonectria theae*) and Tea Tortrix but they have no hold in East Africa. From this it will be seen that it is advisable to keep a close watch for disease infestations and to deal with them promptly even although in other tea-growing districts and countries their incidence may not be important.

This book is well printed and produced with exceedingly good illustrations. Only one error has been noticed. On page 36, *Poria hypolateritia* is listed as a stem disease with symptoms of decaying branches. This should presumably read *Poria hypobrunnea.*

T. EDEN.

STATISTICS FOR COLONIAL AGRICULTURE

A Report on the Organization of Recording and Estimating

(*By K. E. Hunt, published by H.M. Stationery Office,* 1952. *Price* 7*s*. 6*d*.)

This is the only publication on statistics that I have read which does not contain a single mathematical formula in the text. In spite of its title, therefore, there is nothing to dismay or alarm the layman unversed in statistical jargon and mathematical manipulation. It is written in an easy style and contains valuable information for the man in the field—the agricultural or administrative district officer—and gives sound practical advice to persons wishing to carry out statistical investigations.

As its secondary title suggests, it is concerned with only one aspect of agricultural statistics—the methods of collecting data for a survey of agriculture and allied and dependent subjects. The report was written with the British African Colonies in mind and is therefore of particular value in East Africa: it deals with difficulties so often encountered out here which are absent in more advanced societies, and which are frequently omitted in the majority of text-books on statistics and its applications.

One of the major problems, for example, is to obtain information without arousing the hostility of the community. It is realized that this cannot be done by observers coming as strangers to the community, for it takes a considerable time for a new arrival or occasional visitor to be accepted without reserve by all potential informants. Several methods of approach, depending, of course, on the community, are suggested. Briefly, these are as follows: —

(*a*) By introduction through a respected member of the community, e.g., a chief.

(*b*) By working through a member of the community, e.g., Agricultural Department staff (provided they are not associated in peoples' minds with enforcement, etc.).

(*c*) By conducting the inquiry under the name of, or in close association with, some respected institution.

(*d*) By offering, before inquiries are begun, something locally valued, e.g., medical attention or powder for monkey-scaring.

(*e*) By working through children. The danger of "losing face" in this connexion must not be overlooked, but senior schoolboys or college students may be a possibility.

(*f*) Even where children are not to help directly in the inquiry, by asking teachers to give a few prepared lessons on the objects and uses of the inquiry.

(*g*) By including a woman on the survey team to obtain information more easily from women in the community.

(*h*) By discussions with village elders.

(*i*) By use of existing tribal land authorities, even if these are not very active at the present time.

It is suggested that the use of a member of the community ((*b*) above) is probably the best method of approach. The selected person should, of course, have the approval of the authorities of the community, and it is pointed out that any deliberate by-passing of chiefs or others in authority may wreck the inquiry completely.

Other problems encountered are also discussed. The absence of large-scale maps, and complete lists of farms and villages free from discrepancies in definition, make the selection of a sample difficult, and shifting cultivation involving extensive mixed cropping on scattered irregular plots makes it difficult to give the brief precise instructions necessary when recorders are not highly trained. Where large discrepancies occur between villages given in the tax lists and those found in the field it is suggested that samples should be selected by means of maps. The difficulties of recording mixed crops have not been completely overcome but useful suggestions are made. Certain questions are suggested, the answers to which can provide a rough check on the reliability of the recorder.

A section in the report discusses the problems involved in obtaining information about livestock; it is realized that sampling by the ordinary methods will give very misleading results, for stock can be readily moved and hidden. It is suggested, however, that disease control work of a Veterinary Department may give reasonable estimates of livestock numbers in limited areas, and cattle tax records may provide pointers to *changes* in cattle populations. A reasonably reliable estimation of the output of livestock produce meets even greater difficulties than estimation of population, for the only products passing to any significant extent through a bottleneck where they can be measured are hides and skins.

The output of crops is somewhat easier to determine but certain pitfalls for the unwary must be avoided. These are discussed at some length, and methods of overcoming them are described. For example, headlands and paths may be included in the acreage reported under a crop, and if small plots are harvested to estimate the yield per acre, plants are often included which should be left out. These problems arise not merely in general survey work but occur also in crop forecasting, for before any forecasting scheme can operate with any success, it is necessary to have a reliable method of estimating crop production at or after harvest. A section on crop forecasting, although not strictly within the scope of survey work, is included, and the methods at present in use are described. In this section it is stated that "crop condition" can be successfully assessed by observers' judgment, using as comparison a "full" or "normal" crop which is defined as one which is healthy and free from damage by drought, birds or insects, and showing the stage of growth reasonable under these conditions. I still need to be convinced that this rather vague conception is really useful, and, although it may be the only method which can be employed in some areas, it should be used with great caution.

There is, however, little to criticize in the main sections of the report; the lack of theoretical arguments for the basis of the methods used, and the statistical analysis and interpretation of the results can be obtained from text-books on statistics (particularly "Sampling for Censuses and Surveys", Griffin, London, 1949, by F. Yates). The model given in the report is a sound basis for agricultural survey. It is suggested that initially certain selected villages should be used with a view to—

(*a*) testing and developing recording techniques;

(*b*) devising methods of approach which will allow simple records to be made in any community in the locality;

(*c*) selecting a list of the most important data to be collected;

(*d*) preparing a detailed description of the working of the economy so that the significance of its features can be appreciated and statistical data readily interpreted;

(*e*) training the staff in the recording technique.

With the experience obtained the inquiry can be extended to cover a larger area and studies which can only be undertaken after long acquaintance with the people can be initiated in the original villages.

The wider selection of villages in a large area should conform as nearly as possible to a statistically designed sample. It is suggested that where possible one village at least should be chosen from each type of farming region; I would put the minimum at two. Urban areas with the surrounding agricultural land catering especially for the urban market should be treated as separate regions for this purpose. In most cases it is then better to select a certain number of taxpayers from the village and measure the area of the crop under investigation which each man has. In some cases, however, it may be simpler to measure the whole area in the village under the crop, as when, for example, all the rice is planted in one suitable area, and boundaries between plots are indistinct. The yield per unit area is then estimated by means of harvesting a number of small plots and weighing the produce. It is not necessary to estimate yield in all the villages sampled for acreage estimates.

The location of plot sites for harvesting is one of the most difficult problems, since the more complicated arrangements, which theoretically should give reliable results, defeat their own ends if recorders merely substitute less laborious methods. It is suggested that the most complex feasible arrangement is the location of two plots approximately one-third and two-thirds along a diagonal. The use of circular plots is recommended for close-growing crops, broadcast or planted irregularly, and triangular plots where the free rotation of a marker is not possible.

Certain modifications may be necessary for the above simple arrangement. For example, it is not ideal to include the same fraction of large and small villages; it is better to arrange the villages in order according to the number of taxable males, and then to select a greater percentage of the larger villages. If villages are not compact units or if there are large discrepancies between the lists and villages found in the field it is better to use "line" or "area" sampling methods. Recording the length of the parts of a series of parallel lines across a district which lie over a specified crop provides a quick method of estimating the proportion it occupies of the total area of a district. In area sampling a map of the district is divided into sections of equal area and a random sample selected on much the same lines

as that for villages. The disadvantages of area sampling are disregard of community structure, lack of accurate mapping, the difficulties encountered when cropped land forms only a small portion of the area, and the accuracy is limited by the accuracy with which the total area of the territory is known.

The results of extensive surveys must usually be expressed as national totals by converting the sample results. The choice will generally be between multiplying the sample means for each item per taxpayer by the number of taxpayers or multiplying the means per village by the number of villages. There are often advantages in using the taxpayer as a basis for the period of his life when a man pays tax about coincides with the period when he farms on his own under many social systems. Where villages have been arranged according to size, then the acreage or output obtained from the sample is converted to total acreage or output for each size group, and then these individual totals are summed to obtain national totals.

Other sections of the report deal with the tree crops, land utilization, and marketing and distribution of the produce. Advice on the preparation of forms and questionnaires is given in the appendices. Techniques for measurement in the field and the use of maps and aerial photographs to determine area are described.

The report can also be used as a basis for surveys of European farms but the methods employed in England can be applied with little modification in this case and a fuller account can be found in other books (e.g., Yates). It is primarily designed, however, to give information and assistance to those particularly interested in tribal areas and as such should prove extremely useful.

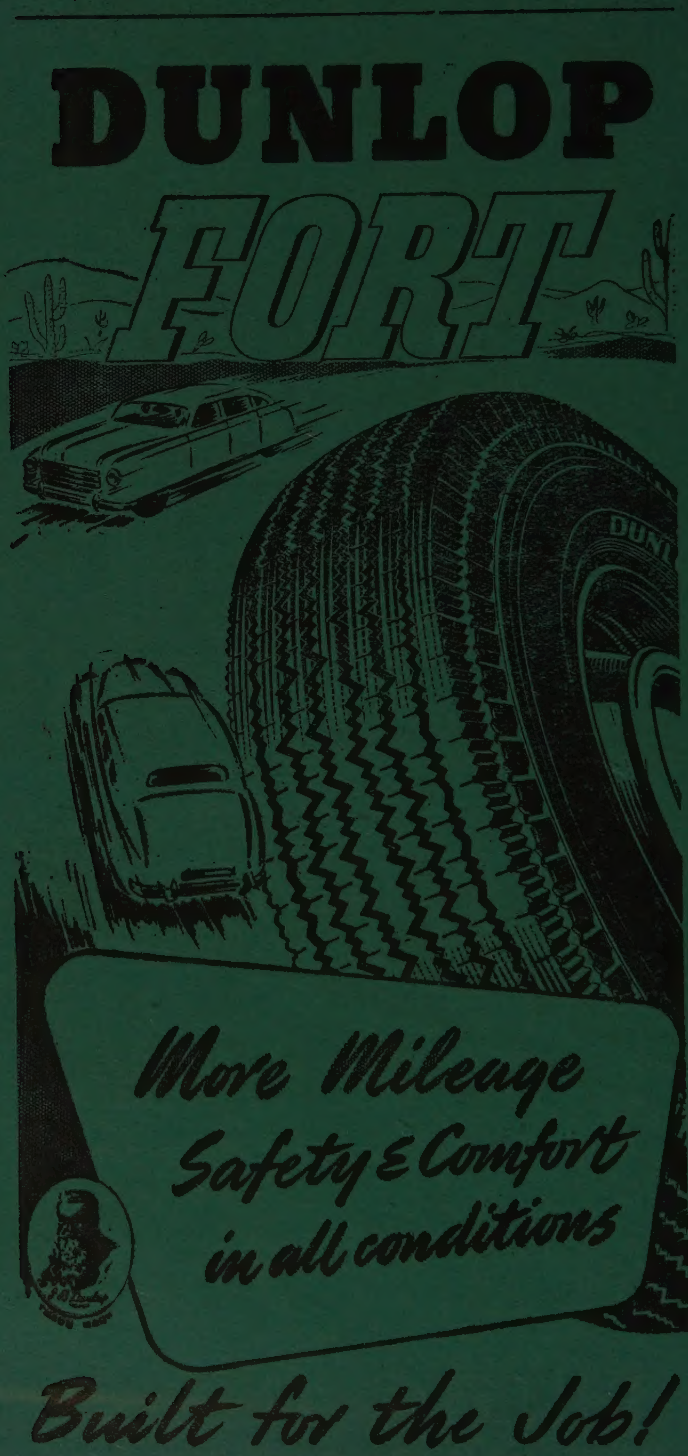
P. ROBINSON.

THE EAST AFRICAN AGRICULTURAL JOURNAL

VOLUME EIGHTEEN
1952—1953

1953
PRINTED BY THE GOVERNMENT PRINTER
NAIROBI, KENYA COLONY

THE EAST AFRICAN AGRICULTURAL JOURNAL
INDEX TO VOLUME XVIII—1952-53


DUNLOP
FORT
DUNL
More Mileage
Safety & Comfort
in all conditions
Built for the Job!
DUNLOP RUBBER COMPANY LTD., BIRMINGHAM, ENGLAND
Depots and Distributors throughout the World
IX/12